ELECTRIC IGNITION FOR MOTOR VEHICLES

W. HIBBERT

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BY

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PREFACE.

The following pages contain the substance of some lectures to motor-men. They attempt to deal with actual questions asked, and to reach a standard suitable for dealing with the examinations of the City and Guilds Institute. I have to thank Mr. Tyson Sewell, A.I.E.E., and Mr. Roche, A.I.E.E., for drawing many of the figures; my assistant, Mr. Howse, for help in obtaining the curve of magneto change shown in fig. 37, and for the magnetic field diagrams. Mr. Hollister also has my thanks for helping me in some of the detailed work.

W. Hibbert.

January, 1907.

PREFACE TO SECOND EDITION.

This edition contains a slight addition on page 18; a brief account of recent original work on the relative value of the spark from coil and magneto on pp. 126, 127, an enlarged reproduction of the Castle Coil diagram, and a few additions to the index. The rapid sale of the first edition indicates the utility of the method here followed.

W. H.

1908.

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ELECTRIC IGNITION FOR MOTOR VEHICLES

CHAPTER I.

GENERAL VIEW OF THE SUBJECT.

1. **Introduction.**—It is proposed to explain the ways in which electric sparks are produced in the cylinders of petrol engines; to consider some of the advantages and disadvantages of the various methods; and to show how the commonly occurring faults may be remedied.

Whether he wishes to do so or not, every motor man is compelled to handle electrical devices, and he is very frequently puzzled by the peculiar way in which the handling must be done. He has to be particular about points which have hitherto never entered his mind. He has to "grow" a new set of ideas, and the process is generally more or less difficult. Questions of all sorts, some practical, some theoretical, are apt to bother him. He is not clear why the connections have to be made in a particular way; nor why the wires must be insulated, still less why the insulation must in some cases be greater than in others. But of all the questions which occur to him, perhaps the most puzzling is this: "Where does the electricity come from?"

It is the aim of this book to give answers to these questions, and to enable the reader to understand

the difference between ampère and volt, the meaning of ammeter and voltmeter, the reason why a condenser assists the action in a trembler coil, &c., &c.

2. **Electricity is Everywhere.** — Take the chief question first, Where does electricity come from? The answer to this is simple. Electricity comes from nowhere: *it is always there.* The world is an electrical world. Electricity is in all the things we see and handle. It is in the metals, the wood, the petrol, the glass, and the leather which go to make up a motor car. It is to be found in the copper wires which conduct and the cotton or indiarubber which prevent conduction. It is in both of these quite as much as in the batteries or magnetos which are employed to get electric currents. When he has read so far, the reader may ask, If this be so, why are batteries employed? a question which goes to the root of the matter.

Batteries are not employed to get electricity, but rather to get electric currents. The electricity is there all the time; the battery is wanted to *set it in motion.* There is a wonderful difference between *electricity* on the one hand and a *current of electricity* on the other. The difference is the same as that between *air* and *wind.* Air is a substance which lies round about us. We live in it as fishes live in water. And we commonly disregard the air, as the fishes probably disregard the water, for the reason that we and they are ignorant of the presence of these atmospheres under ordinary conditions. But if the air is *set in motion,* we recognize its motion at once. *Its presence is made known to us by its motion.* We do not ask where the air comes from, but rather, What sets it in motion? And we learn, in answer to this question, that the air moves because the pressure has been changed; the pressure has been made greater at one place than it is at another

This illustration may serve to suggest to the reader the actual state of the case on the electrical side. Although we live in and among electricity, we fail to recognize its presence because it is evenly distributed. But if it be set in motion, then we are at once made aware of *its movement. The current* of electricity does something which the electricity itself could not.

Further, the motion of electricity—the current—is due to a disturbance of electric pressure. When electricity moves, it is because something or other has produced a difference of electric pressure between two places. At one place the pressure has been made higher; at another place it has been made lower. This being so, electricity will pass from one to the other place unless there is an absolute barrier in the way. It will move more quickly if the intervening space is filled with good conductors. Thus it appears that if we are to know anything about electric currents, we must find out what things act as barriers, what things act as conductors, and by what contrivances it is possible to set up differences of electric pressure. We may anticipate so far as to say that an electric battery and the substances inside it have (like other things) plenty of electricity in them, but that the chemical substances exercise a kind of thrust on this electricity, a thrust which would drive the electricity out at the positive terminal and suck it in at the negative. If, however, the terminals simply stand in the air, this electric force or pressure can do nothing. But if a conductor be run between the two terminals, then electricity—in response to the chemical thrust—moves out at the one terminal and in at the other.

3. **Conductors and Insulators.**—Electricity behaves in a way comparable with air, water, steam, or anything else which can be set in motion.

In some bodies it can move more or less easily, in others it moves with difficulty. The first class are called conductors, the second non-conductors or insulators.

But electricity shows a great peculiarity. When pipes are arranged to convey water, the pipes act as insulating walls to prevent leakage; the water flows through the hole inside the walls.

With electricity, the flow takes place, not through an empty space inside, but through the very substance of the conductor. Copper is one of the best conductors of electricity, though all metals are fairly good. But conductivity depends on dimensions as well as on the metal. A thin copper wire (that is, a wire of small sectional area) is a poorer conductor than one of larger section.

Again, a long wire offers more resistance than a short one.

By attending to this point, the engineer can always get a stronger or weaker current, because a given electric pressure produces a more rapid flow in a circuit that conducts well, and a less rapid flow in a circuit that conducts badly.

When dealing with the flow of water, the pipes, as they are called, are used to prevent the water flowing in undesirable directions. In the same way, electrical conductors have to be surrounded by substances through which electricity cannot flow. These are called insulators, and are made of air, cotton, silk, indiarubber, shellac, ebonite, paraffined paper, &c.

The insulators used vary with the method of using and the degree of pressure. In telegraphy, the wires are surrounded by air; in ignition work, by paper, shellac, ebonite, indiarubber, and silk. The choice depends on the pressure employed. For example, in low-tension magneto work the magneto wires are covered with shellac and cotton;

while the external conductors are coated with indiarubber. In high-tension work, a silk covering for the wire is necessary inside the instruments, and the outside wires must have a much greater thickness of indiarubber. A greater thickness enables the indiarubber to stand a greater electric pressure without bursting, just as a thick-walled pipe can stand a higher pressure than one whose walls are thin.

For ignition purposes, it is important to notice that air is a non-conductor or insulator, and that, like every other insulator, it can be burst through if the electric pressure is raised high enough. It is also important to notice that water is a fairly good conductor of electricity, and that if it gets into the pores of insulators, it breaks down their insulating value. Cotton and paper are very apt to absorb water, and it is for this reason that they are often impregnated with shellac or with paraffin wax. These substances prevent water getting into the pores quite so readily.

4. **Circulation of Electricity.**—However good the conductors may be, it is not possible to get a continuous flow of electricity unless they are arranged in a *circuit*. If only the positive end of a battery or a working magneto is joined to a long insulated wire, there is a flow of electricity into the wire, *but the flow is only momentary*. The immediate effect of the flow is to increase the electric pressure in the wire, and this soon rises to the point at which it is equal to that exerted by the generator. As soon as this takes place, equilibrium is attained, and that generator can force no more electricity into the wire.

The case is similar to that of a long pipe (closed at the end) connected to a boiler. When the pipe is first connected to the boiler, there is a transient rush of steam into the pipe, which goes on until

the pressure of steam in the pipe equals that in the boiler; the flow then ceases.

To get a continuous flow of steam, the end of the pipe must be open to the air so as to prevent the pressure rising at that end.

In a similar way, in the electric case, the conductor which runs from the positive end of the accumulator must sooner or later run to the negative end, in order to keep the pressure different at its two ends. By so doing, one end (the positive) is kept at a high pressure, and the other at a low pressure. Electricity will be urged into this external conductor at the positive end and out of it at the negative end. Hence there will be a *circulation of electricity through a conducting circuit.*

A direct practical consequence of this feature of electricity is that everything used as a part of the circuit must have an outlet as well as an inlet. Both are necessary. The best known analogy to this is that of the circulation of the blood. The heart is the generator of the current, not the generator of the blood. It raises the pressure of the blood at one end and drives the blood out. But it also reduces the pressure at the other end, and so induces the blood to flow in there. Hence the circulation. But if the arteries, veins, &c., did not form a *circuit* there could be no continuous *circulation*. There might be a transient flow, but it must stop almost immediately.

These general ideas having been explained, it will be advantageous to say a few words first on "high" and "low" tension; secondly on the conditions under which an explosion spark occurs.

5. **High and Low Tension.**—The ultimate object of all the contrivances employed is to get a spark between two conductors arranged in the engine cylinder. There are two distinct ways of doing this. One is to arrange a spark plug with two

wires at its base, the distance between these points varying from one-twentieth to one-thirtieth of an inch. Now the air which lies between these points is an obstacle to the flow of electricity, and offers so much resistance that a very high electric pressure is needed to burst through. Hence all the ways of working which involve a spark plug may be called "high-pressure methods." They are more commonly called "high-tension" methods. The other, or low-tension method, of getting a spark is to do without a spark plug and arrange that two conductors shall actually *touch* in the cylinder. Of these two conductors, one is fixed and insulated from the walls; the other can be moved aside by simple cam mechanism. An electric generator is joined to these points, and as the conductivity of the circuit is great, a very good current can be maintained even by a low electric pressure. It is arranged that when this current is at its highest value, the cam shall separate the movable conductor from the fixed one. The gap thus formed would of itself prevent the generator setting up any current, but is not able to stop instantaneously the current now actually flowing. The current which was flowing just before the formation of the gap has *momentum*: it cannot stop instantly. Hence it is carried across the aerial obstacle, and a bright spark accompanies the separation of the points. Seeing that the magneto employed for this kind of work is required merely to establish an electric current in a good conducting circuit, and that a low electric pressure suffices for this, it has become usual to call this the "low-tension" system.

This distinction between the "high-tension" and "low-tension" methods must be kept in mind. It will be easy to understand that greater care must be given to insulation where high tension is em-

ployed, seeing that the chance of leakage is increased by the higher pressure.

The distinction can be put in a few words. In the high-tension systems a spark has to be driven across an air gap; that is, in an incomplete circuit, and a high pressure is requisite.

In low-tension systems an electric current already flowing in a conducting circuit is driven by its own momentum across a gap suddenly formed in its path. Consequently a low-pressure generator suffices.

Let it be noted that electric pressure is measured in *volts*, and that "voltage" is now a technical word often used for electric pressure.

6. **Sparking Pressure.**—To get an electric spark, it is requisite to "burst" the wall of air that separates the two points. A low pressure (voltage) will not do it: the air is too strong, just as a boiler shell is commonly too strong to be burst by the steam pressure. If the electric pressure rises high enough, the air will give way and a spark occur.

The voltage required depends on the thickness of air, and also on the shape of the conductors. For ordinary spark plugs in air, the sparking pressure will vary from about 3,000 volts to 5,000 volts, according to the thickness of air between the points. But ignition sparks are not taken in air. They are required in a mixture of air and petrol vapour, and at a time when the mixture has been compressed to four or five times the atmospheric pressure. Now as the compression increases, it becomes more difficult to burst through the vapours: a higher pressure will be required. The conditions inside a cylinder at the moment of ignition are rather too trying for experiment, and therefore not much definite information exists. But it is probable that the electric pressure actually required may be as high as 10,000 to 20,000 volts.

7. **Timing.**—The spark has to be "timed." In a gas or petrol engine there is a spark every two revolutions or every fourth stroke. The explosion stroke, or the stroke in which the work is done by the expanding gases, leaves the cylinder full of spent vapours. In the next stroke, the piston pushes these out through the exhaust valve. In the next stroke, the piston draws in a mixture of petrol and air, and in the following stroke compresses the mixture ready for the spark to explode it.* The cycle of strokes is then repeated.

Theoretically, the proper time for exploding is at the end of the compression stroke, when the compression is a maximum, for this would lead to the best mechanical result. But "sparking" and "exploding" are not the same thing. When the spark occurs, it at once explodes the explosive vapour round the points, and the flame then spreads as an explosion wave through the rest of the mixture. This takes time, and although the time is short, it must be taken into account. There is a brief interval between the spark and the full force of the explosion. To get the full effect of the explosion, therefore, the spark ought to occur slightly *before* the end of the compression stroke. This is called "advancing" the spark.

How much the spark ought to be advanced, depends on the speed of the piston and the velocity of an explosion wave. At top speed a piston travels about 120 or 150 feet a second. An explosion wave travels with very varied speed, according to the nature of the "mixture." From Berthelot's work on the velocity of explosion waves, the author calculates that in a petrol engine cylinder the flame may travel about 8 to 10 yards per second—say

* The mixture is compressed before sparking, because the mechanical effect obtained is then very much greater.

about 300 inches per second. If we assume that the distance from spark to piston (at the end of its stroke) is about 1 inch, the explosion wave will take about $\frac{1}{300}$ of a second before its full force can be felt, and in that time the piston would travel about half an inch.

Therefore, to get the greatest effect, the spark must come in "advance" of full compression by about $\frac{1}{300}$ of a second. The exact position has to be found by trial: the foregoing calculation is too unreliable for definite action, and is only given to make the principle as clear as possible.

When the car is to go slowly, the conditions must be altered. The piston will travel more slowly, and if the spark came at the same piston position as before, the full force of explosion would be felt before it gained the end of the compression stroke. This would give rise to "back-firing," which would tend to stop and reverse the engine.

Hence the spark must be retarded in comparison with the piston. This "retardation" may be carried so far that the spark does not take place till after the piston has travelled some part of its fourth stroke (commonly called its explosion stroke). In this case the mechanical effect arising from the explosion is diminished because the mixture is less compressed when the explosion takes place. This is in fact an additional way of regulating speed: the more the spark is retarded, the less vigorously will the car be urged by the exploding vapours.

CHAPTER II.

BATTERIES, COMMUTATOR, AND COILS.

PRELIMINARY SURVEY OF CIRCUIT.

We have seen what is required for ignition and the conditions under which it ought to be produced. Two chief methods are employed to get the requisite electrical pressure: one is the battery system, depending on the chemical action of a cell; the other is the magneto method, depending on the action of a magnetic field. For reasons which need not be now given, we shall first describe the battery method, and shall begin by a hasty survey of the necessary apparatus.

8. **Battery System.**—In fig. 1, *B* is a battery of two accumulators; *S* is a switch; *C B* is a contact

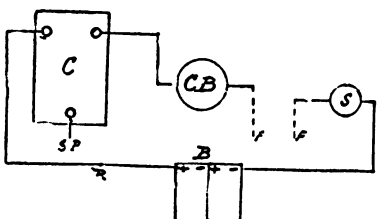


Fig. 1.—Arrangement of simple battery circuit.

breaker; *C* is a coil (induction coil). The use of each part is as follows:—The switch *S* enables the user to put the battery in or out of action. The coil *C* raises the electric pressure. It contains an iron core and two coils of wire, known as primary

and secondary. The secondary is connected to the spark plug *S P*. The contact breaker *C B* is to interrupt the current from the battery at given moments. Both terminals of the battery are joined to the primary coil in *C*, but one connection is made by a wire direct, the other is made through the switch *S*, the frame of car *F*, the contact breaker *C B* and a wire.

Let us explain the use of the framework. In the arrangement sketched, the necessary thing is that the current from the battery should pass through the primary coil in *C*, and also through the contact breaker blade. Provided that this is done, it is of no importance how the current gets back to the battery. Any conducting path will serve, and the metallic framework does this excellently.

To ensure these conditions, the wires from the battery to coil, and from the coil to contact breaker, are not only run direct, but are carefully insulated. Beyond the contact breaker, it does not matter how the current gets backs. Hence it is led from the outlet of *C B* to the frame and through this to the switch *S*, and so on to the negative end of the battery.

This use of the framework not only saves a quantity of wire; it frees the space round the machinery from possible wire entanglements.

The "framework" connection is generally referred to as a connection to "earth," because of the telegraphist's habit of using the "earth" as a return conductor for his circuits. French motorists use the name "masse" and the symbol *M*. We shall use the name "frame" and the symbol *F*, though occasionally "earth" will be employed.

Here we may explain what is meant by "short circuit." In fig. 1 all the wires ought to be insulated, except the ends which go to the frame *F* (earth). Suppose that the insulation wears away, or is torn off at some such point as *R*, and that the

wire at this point touches some part of the metallic frame. There is then a *short circuit:* for a current can flow from the + end of *B* to the point *R*, then to the frame, and from this through *S* to the end of *B*. Such a current would not flow through the primary coil, and would be useless. Nay, it would be injurious, for it would exhaust the battery very

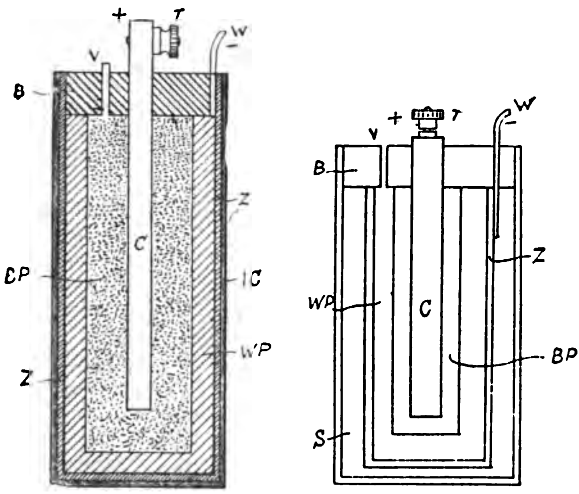


Fig. 2.—E.C.C. and Hellesen dry cells.

speedily, and break down the service. The phrase "short circuit" therefore refers to any easy conducting path which shunts the current away from the working apparatus.

BATTERIES.

9. **Dry Cells.**—Fig. 2 shows typical forms of dry cells. In each of them there are four essential

parts, namely, a carbon plate or rod *C*; a zinc cylinder *Z*; a black mixture or paste *B P* of granules of carbon and a mineral called manganese dioxide; a white paste *W P* moistened with a solution of sal-ammoniac. This white paste is sometimes made of flour and plaster of paris, sometimes of other substances, which form a pasty mass on being moistened. Its object is to place a semi-fluid wall between the manganese granules on the one side and the zinc cylinder on the other. The flour and plaster of paris serve for this purpose. The solution of sal-ammoniac serves first to convey the current through the paste, flour and plaster of paris not being conductors themselves; it serves secondly to act chemically on the zinc, as explained below.

Beside these essential parts, there is an insulating case *I C* covering the zinc; a layer of bitumen *B* at the top with a vent *V* for the escape of gases. The Hellesen cell has an outer case of millboard; the space between this and the zinc being filled with sawdust *S*.

The carbon rod is provided with a terminal *T*, which acts as the positive end or pole of the cell. A wire *W* is soldered to the wall of the zinc, and serves as the negative end of the cell. The soldered joint must be carefully protected from the action of the paste.

The dry cell battery used on a car contains four of these cells joined in a *series*, that is, the positive end of cell *A* joined to the negative of cell *B*, and so on. This leaves two free poles, namely the negative of cell *A* and the positive of cell *D*. Fig. 3*b* is a diagram of these, and fig. 3*a* shows two accumulators similarly connected.

In trying to explain the action, a slight difficulty arises unless the student has some chemical knowledge, but the least informed reader

may profit by the following statements. Notice that when the terminals are joined by a conductor, the zinc begins to be acted on chemically by the sal-ammoniac, and is slowly dissolved into the paste. At the same time a gas named hydrogen would be formed at or near the carbon plate if it were not for the action of the manganese dioxide. This black substance is rich in oxygen, and has the power of burning hydrogen gas bubbles. It is, indeed, used to prevent their formation.

It will be evident that as the sal-ammoniac solution and the manganese dioxide are changed by these actions, there will come a time when they have been more or less destroyed as such. The

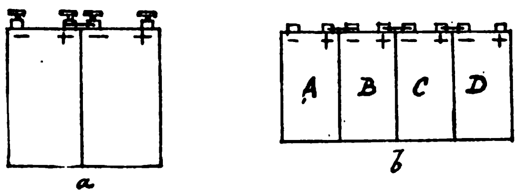


Fig. 3.—Cells joined in series.

cell will then be practically exhausted, and must be replaced by a new one.

Realizing these points, the action may further be described as follows. The zinc serves as a kind of fuel. By its chemical combustion a certain quantity of energy or working power is obtained. In the chemical turmoil of the atoms, this energy is spent in urging electricity round the circuit, the current leaving the cell by the positive terminal and returning by the negative. These statements will be repeated with variations in the next few paragraphs, so that a careful reader will be able to master their general significance.

The full statement of the chemistry is given in an Appendix.

10. **General Remarks on Dry Cells.**—There are very many forms of dry cells, but their general construction is more or less like that shown in fig. 2. Messrs. Siemens, the makers of the Hellesen cell, make others like the Obach, and also a special type known as the "Traction" cell for use in ignition work. The value of all such cells is largely determined by the care and experience used in the manufacture.

All forms however are liable to some deterioration by being kept in stock. To prevent this deterioration some cells are made up with the various solid substances in position and are kept quite dry till their working life is to begin. The requisite amount of water to make paste has then to be added, and they are almost immediately ready for use. The same purpose leads to such cells as the Moto-Capsule" cell made by Mr. Fuller. In this the liquid chemical solution is kept apart in a capsule contained in the cell. In this state the cell remains intact for any length of time, but can give no current, because the solid substances are not conductors. When the working life of the cell is to begin, it is brought into a proper state by piercing the capsule so that the liquid can flow over the other substances. The chemical store of energy then becomes available. An instrument is provided for piercing the capsule.

After being started in this way, the cells are of course on the same footing as those previously mentioned.

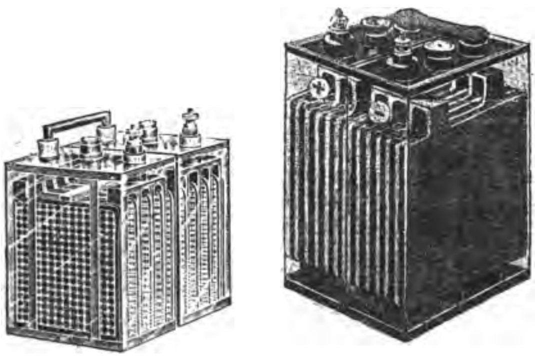
11. **An Accumulator.**—The essential parts consist of (1) a positive plate; (2) a negative plate; (3) a suitable liquid. The general appearance is shown in figs. 4 and 4*a*.

(1) The positive plate is formed of a cast lead

grid with square or rectangular holes. The holes are filled with a dark brown oxide (or rust) of lead known as peroxide of lead.

(2) The negative plate is formed of a cast lead grid, the holes of which are filled with finely-divided, spongy lead.

(3) The liquid consists of dilute sulphuric acid, made by mixing 1 part of sulphuric acid (pure vitriol) with about 4 or 5 parts of water, these measures being by volume. Besides these three essential



Figs. 4 and 4*a*.—E.P.S. and Hart cell.

parts, there must be (*a*) a containing vessel, which is made of ebonite or celluloid; (*b*) a projecting lug from each plate to which a suitable terminal is attached; (*c*) a vent hole to provide for the escape of the gases liberated at or near the end of a "charging" operation; (*d*) suitable insulating separators to prevent the positive and negative plates touching. These are made of perforated and corrugated sheet ebonite or thin sheets of prepared wood.

The separators also serve to prevent the disintegration of the plates. The little blocks of peroxide which fill the holes of the positive grid have a tendency to fall out after some time, and the separators help to support them in place. They have to be so constructed that while giving mechanical support to the plates, they do not materially interfere with the conductivity of the liquid. The perforations in the sheet ebonite serve this end. This is also provided

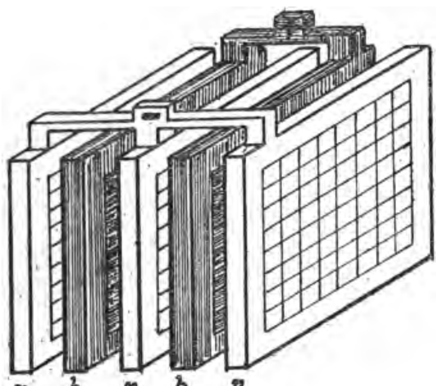


Fig. 5.—Two positive plates interleaved with three negatives.

for by the pores of the wooden or similar separators.

To get equal capacity an extra negative plate is frequently used. A common arrangement is to put three negatives and two positives in one cell. These are interleaved, as shown in fig. 5. The three negatives are joined to a common lug, as are also the two positives. Thus there are only two terminals. The current taken from the cell comes in part from each positive plate, and on returning

to the negative terminal of the cell divides to the three negatives and from them passes through the acid on its way back to the positive plates regarded as the starting-point.

In almost every case the negative plates exceed the number of positives by one.

On the top of each accumulator cell used for ignition work there appear the two lugs (one from each plate) and the vent hole. The lugs generally have terminals fixed to them, and, in order that they may be clearly distinguished, the positive terminal is painted red, the negative black.

The vent hole is usually closed by an indiarubber stopper to prevent spilling. This must be removed during charging.

Some stoppers are made with a kind of valve. They are perforated by a central hole into which is fixed a short glass stem with a small bulb at one end. In the middle of this bulb is a very small hole, large enough for gas bubbles to escape, but too small for liquid to run through. Consequently, gases liberated by the charging current get away, although the acid is quite unable to leak out, even though the cell be overthrown.

The accumulator battery used on a car consists of two cells joined in *series*, that is, the positive terminal of cell *A* is joined to negative of *B* by a stout conductor. This leaves the negative terminal of *A* and the positive of *B* free for connecting to the external part of a circuit (see fig. 3*a*).

12. **Exhaustion of Cell.**—A full statement of the chemistry is given in an Appendix. The following is a simpler account.

While a current is being taken from the cell, the sulphuric acid is uniting with the spongy lead and destroying it as such. Every moment the current continues, more and more of the lead is consumed, until finall so much is gone that the rest cannot be

got at by the acid. This arises from a very curious reason. The chemical action does not actually destroy the lead. The metal and the acid form a chalky white compound called sulphate of lead, and this is deposited as the action goes on. In time the accumulation of this in the pores of the spongy lead clogs them up, and the rest of the metal is not available. The cell is exhausted because the rest of the fuel cannot be reached.

At the same time, the peroxide of lead on the positive plate is changed to sulphate. The peroxide of lead acts as depolarizer, that is, it prevents bubbles of hydrogen gas forming, and, in burning these bubbles up, it is itself changed and degraded to sulphate. Thus the pores of the positive plate get clogged like those of the negative. By the formation of *white* sulphate of lead in their pores both plates change colour. The positives become a light brick colour. The negatives become grey.

Seeing that acid is being taken by both plates to form these sulphates while the water remains, the liquid in the cell must get weaker every moment the current continues. Its density must fall. This fall in the strength of the acid contributes to the exhaustion of the cell, because it involves a fall in the electric pressure. A weaker acid gives less than two volts even if the plates are not exhausted, and it causes a much greater fall on the working value of the cell (par. 33).

When about half the active materials in the plates has been changed to sulphate, the cells are of no use. They need recharging, which is done by sending a reverse current through, using a battery or dynamo of higher voltage to force it through. The effect of the charging current is to do three things.

1st. It decomposes the lead sulphate formed on the positive plate, changing it into lead peroxide and sulphuric acid.

2nd. It decomposes the lead sulphate formed on the negative plate, changing it into spongy lead and sulphuric acid.

3rd. The fresh acid formed in the pores of both plates is restored to the liquid by diffusing out of the pores where it is formed.

Thus both the plates and the liquid are brought back to their original state, and the cell is charged. Further details are given in the Appendix.

The student will find that all the changes in the colour of the plates, &c., can be accounted for by the formation of white sulphate during discharge and its removal during charge. In a similar way, the changes in strength of acid explain the changes in electric pressure.

13. **Special Features of Accumulators.**—An accumulator is a kind of cell with markedly valuable features. It gives a high electric pressure, namely, two volts. It is to be noted that this value (about two volts) is the normal value. While being charged, and for about forty-five minutes afterwards, the pressure has a transient high value. It may be as high as 2·6 volts, slowly sinking to something just over two. Its liquid has a higher conducting power than any other formed by dissolving substances in water. Its internal resistance to a current is therefore much smaller than that of any other type of cell of similar shape and size. If the acid be not too strong, it will keep its charge—or most of it—for a reasonable time.

It is worth while noting that there is a temptation to use acid of undue strength because it sets up a higher electric pressure, and so far gives advantages. But these are obtained at too high a price. A cell thus made cannot keep its charge so well. The stronger acid acts on the spongy lead even when no current is being taken. It also acts slightly on the peroxide of lead. Hence, even in idle time,

some of the active material on each plate is rendered inactive by chemical actions, as explained in the Appendix.

14. **Commutator: Contact Breaker.**—Batteries are not in use all the time a car is running. They are brought into action just before the moment at which sparking is wanted. In the interval between sparks the battery is disconnected from the circuit, and the device by which this is done is called a commutator, or a contact breaker. These names are used rather vaguely. A commutator ought to be a device for commuting the current or turning it from one channel to another, as when a battery serves successively four sparking coils for a four-cylinder engine. A contact breaker ought to break the circuit simply.

Common usage is however gradually telling against this. Fig. 6 (with terminals at T_1, T_2, T_3 and T_4) shows a true commutator. But fig. 7 is also generally called a wipe commutator, although it is a wipe make and break. The names given in this paragraph are chosen accordingly. The matter is complicated by the presence of a make and break in the coil trembler, the word "trembler" often covering the whole coil.

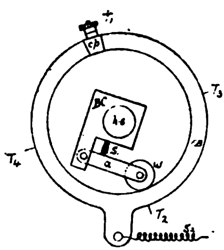
Figs. 6 and 7 show two forms of commutator; fig. 8 shows a contact breaker sometimes called a make and break; fig. 8 is the De Dion contact breaker, now very little used on new cars.

In fig. 6 the half-speed shaft *h s* carries a casting *B C*. At the smaller end of this is a pivoted arm *a*, the other end of which carries a wheel *w*. All these are carried round by the half-speed shaft, giving the arm *a* and the wheel *w* a tendency to fly out. This tendency is increased by a spring *s* which has to be compressed to get the apparatus into the containing fibre box *F B*.

This box is made of an insulating material known

as vulcanized fibre. The shaft *h s* passes through a hole in the middle of the box, but so loosely that the box is not carried round. It is kept stationary by means of the spring *s* attached to a lug projecting from the box. At four points of the fibre box are fixed terminals T_1, T_2, T_3, T_4, fig. 6 (only T_1 is drawn). Each terminal is soldered to a small metal connecting piece *c p* fixed in the wall of the box and coming flush to its inside face.

It is now possible to follow the action. The circuit connections are made by joining a wire to T_1, the other through the frame to *h s*. Whenever



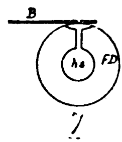


Fig. 6.—Commutator. Fig. 7.—Wipe contact breaker.

the wheel *w* comes to the metal piece *c p*, the half-speed shaft *h s* is joined to the terminal *T*, through *B C*, *a*, *w*, and *c p*. This contact lasts only so long as *w* and *c p* are touching, and this can be adjusted by choosing a suitable breadth for *c p*. It is also evident that the moment at which the contact is made can be altered by rotating the fibre box *F B* on the half-speed shaft. By pulling it in the direction in which *w* is rotating, the moment of contact is "retarded." By allowing the spring *s* to pull it in the contrary way, the moment of contact is hastened or "advanced."

The "advance" or "retard" of the fibre box *F B*

on *h s* is managed by pulling a cord attached to the lug; which is done by simply turning the timing lever handle.

In fixing this on the half-speed shaft, it is necessary to provide for "advancing" and "retard ing" the moment of contact by the right amount. The normal position is for contact to be "on" when the piston is at the top of its stroke. The commutator must be placed on the shaft so as to make its terminal have contact with the wheel *w* when the piston is at the end of the cylinder. The driver's timing handle must then be fixed in the middle of its travel, and the cord and spring which control the fibre part of the contact breaker must

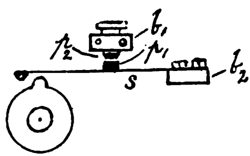


Fig. 8.—Make and break.

then be adjusted to hold it firmly in this position till the timing handle is moved one way or the other.

The letters T_2, T_3, T_4 show the position of three other terminals which are provided when a four-cylinder engine is to be worked. For a two-cylinder engine terminals are provided at T_1 and T_2.

Fig. 7 is known as a "wipe" contact commutator, because the fixed brush blade *B* rubs against or wipes the circumference of the fibre disc *F D*. In this disc is a metal segment running from the shaft to the circumference. Wires are joined to *B* and to the half-speed shaft, so that the circuit is broken except during the short time in which the

metal segment and the blade *B* are in contact, as shown in the diagram.

In the contact breaker fig. 8, *s* is a spring blade carrying a platinum stud p_1. Just above this is a second platinum stud p_2, which is carried by an insulated screw block b_1. One end of the circuit is joined to b_1, the other through the frame to b_2. The circuit is completed during the time in which the cam presses p_1 and p_2 together. This is known as a "positive" make and break or contact maker, the effect of the cam being to close the circuit.

Another contact is shown in fig. 9, though the scheme of wiring and the contact breaker given in

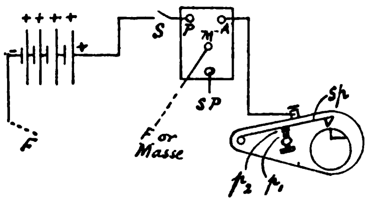


Fig. 9.—Circuit with make and break.

it are those used on older De Dion cars. The contact breaker is not a "positive" make and break. The cam keeps the platinum points p_1, p_2 apart until it allows the end to fall. The spring *s* then brings p_1, p_2 together. It is so adjusted that it makes a vibrating series of contacts, thus making and breaking the circuit several times during one release.

Where these commutators, &c., are for use with single-cylinder engines they carry only one contact piece. For two-cylinder engines a wipe carries two blades: in the contact breakers the cam has two projections 180° apart. For four-cylinder engines these are increased to four (see fig. 23).

15. **Platinum Points.**—In apparatus like that shown in figs. 8 and 9, as well as in many others where contact points are used, it is important that the points should be made of platinum. The reason is :—There is a great tendency for sparks to occur at such points *when the contact is broken*. The momentum of the current tends to carry it across the air gap. Now such sparks are very trying to ordinary metals. The heat tends to melt them not bodily, but locally, that is at the point from which the spark springs. This makes it desirable that the contact points should be made of a metal which does not melt easily. Platinum is chosen because it is most difficult to melt; more difficult even than gold or wrought iron. It is true that wrought iron or nickel have very high melting points, but they are subject to another weakness. The spark tends to make them rust at the points, so that they soon become too dirty to make good contact. Platinum does not rust. and therefore keeps clean. Even platinum however tends to get pitted with little holes due to fusion.

Sparking or Induction Coils.

There are two varieties of these, trembler and non-trembler coils. We shall take the non-trembler type first.

16. **The Non-trembler Induction Coil.**—This consists of three essential parts. (1) An iron core; (2) A primary coil; (3) A secondary coil, figs. 10 and 11.

(1) The core consists of a bundle of straight, thin iron wires, about 6 to 7 inches in length, and in sufficient number to make the total diameter about three-quarters of an inch. The core is covered with a layer of tape or brown paper or some other insulator.

(2) The primary coil is wound over the core, after the latter has been insulated as mentioned.

It generally consists of about three layers of copper wire No. 20 or 22 (about $\frac{1}{20}$ inch diameter). This wire is insulated, being covered by the maker

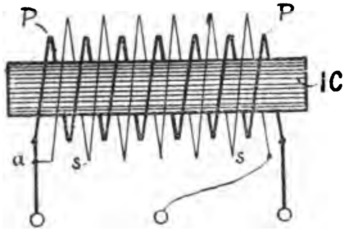


Fig. 10.—Diagram of non trembler coil.

with a double serving of cotton for the purpose of preventing leakage between neighbouring convolutions. When this primary coil is complete, a light insulation is sometimes placed over it.

(3) The secondary coil is wound outside the

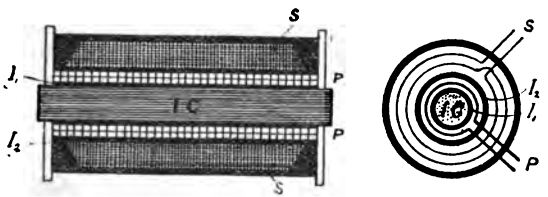


Fig. 11.—Rough sections of non-trembler coil.

primary. The wire is much thinner, and insulated by a covering of silk. The size of wire is about No. 40 or 44 (approximately 0·0048 and 0·0032 inches diameter), and there may be as many as 10,000 or 15,000 turns. Between each layer of wire

of this secondary coil it is usual to place one or more layers of paraffined paper. This is to insulate one layer from another more perfectly, the silk covering not being able to stand the very high pressures produced in this coil.

In figs. 10 and 11 *I C* represents the iron core; *P* the primary winding; *S* the secondary winding; I_1 the insulation between core and *P*; I_2 the insulation between *P* and *S*. In the cross section, fig. 11*a*, the primary is represented by only one convolution; the secondary by two. This is merely to relieve the diagram of complexity. The usual practice in making ignition coils is to join one end of the secondary coil to one end of the primary, as shown in the diagram fig. 10 at the point *a*. This common point is afterwards joined to the frame, as may be seen in fig. 1.

It will be best now to show how this coil works, so that the use of its various parts may be clearly understood. There is no great difficulty in the matter if the points are examined *one by one*. The ideas involved are probably all new to the reader of this book, but sufficient illustration is given to make the matter fairly clear.

17. **Coil Involves Two Circuits.**—An induction coil involves the use of two independent circuits. Fig. 12 indicates this, as will at once be evident if an attempt be made to follow the conductors. In drawing the diagram, many liberties are taken. For example, the primary and secondary coils are side by side instead of *S* being over *P*, but this is to prevent lines overlapping, with a consequent confusion of the reader. The other figures which follow will correct any error arising from the distortion.

The two circuits now to be traced are called the primary and the secondary circuits, because there are no electrical effects in the latter till a current

has been passed through the former. It will help the reader if he keep in mind the fact that the copper wire of both primary and secondary circuits contains plenty of electricity before any action is established. Primary circuit, fig. 12. This includes a battery *B*; the primary winding *P* of an induction coil *C*; a contact breaker *C B*; a switch *S*; insulated wires w_1, w_2, w_3, and w_4 connecting these together in a conducting circuit. Notice that w_3 is dotted and marked *F*, intimating that this

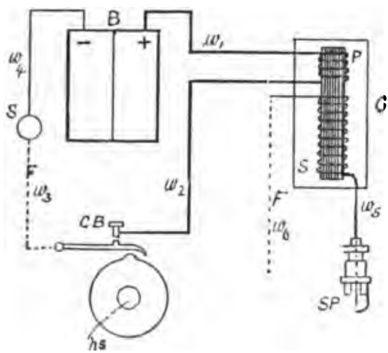


Fig. 12.—Primary and secondary circuits.

part of the circuit is generally made through the frame or "earth." This primary circuit is incomplete till the cam pushes the two points of *C B* together. It is evident that during the time these points are held together, a current will pass in the primary circuit, and then suddenly cease.

We may put this in another way and say that during most of the rotation of the half-speed shaft there is no circuit, and the battery *B* cannot establish a current. But while the make and break points are touching, a current will flow and then be

suddenly broken. This occurs once every revolution. It is important to notice that the primary current cannot and does not touch the secondary circuit. What, then, is its work? *It magnetizes the iron core for a moment, the magnetism vanishing quickly when the primary current ceases.*

The spark in the secondary circuit is due to rapid magnetic charges in the iron core, and these depend on rapid changes in the primary current.

It is advantageous to summarize the course of the primary current as follows:—

From the + end of the battery through w_1, P, w_2, $C\ B$, w_3 or frame, S and w_4 to the — end of the battery, and through it to the starting-point.

18. **The Secondary Circuit. Sparking Plug.**—The secondary circuit can be traced in fig. 12. What is called the "live" end of the secondary winding is joined directly to the central wire of $S\ P$. The second end (earthed end) connects to the other wire through the frame and engine body, as shown by the dotted line.

Strictly speaking, the word circuit has here a slightly different meaning. In the case of the primary circuit there is a continuous *conducting* circuit, at any rate when the contact points at the commutator are closed. But the secondary circuit consists of the secondary winding of the sparking coil, the spark plug and the two wires which are necessary to join them together. The air gap at the spark plug is never bridged across except by the spark itself, and as the air is a non-conductor, electricity does not flow steadily through it. There is no flow until a bursting electric pressure is reached, and then there is a violent rush through the broken-down air-wall.

There are innumerable forms of spark plug. Fig. 13 will serve to indicate the necessary parts. The spark takes place between the ends of two

wires, p_1 and p_2; p_2 is fixed on the metal screw near the end, and is therefore in contact with the engine body when the spark plug is screwed home. Connection to it is reached through the frames; p_1 is carefully insulated. It runs through the middle of a cylinder or cone of porcelain or mica, *M*. Its upper end is fastened either to a brass rod or to a brass cap which is fixed on the other end of M. A screw terminal, T, is in contact with the wire being screwed on a central pin let into the brass cap. By this terminal a wire from the high-tension terminal of the spark coil is connected to

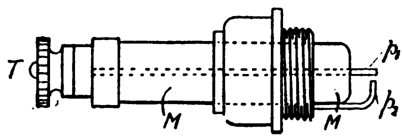


Fig. 13.—Spark plug.

the wire p_1, and thus brings it to a high pressure above p_2.

We have now to explain how the very high voltage required to burst down the air is obtained in the secondary circuit. Already it has been said that it is due to the great magnetic changes produced by the primary current. This statement will probably convey little meaning to the reader, and cannot very well do so until the meaning and action of a magnetic field are explained. This must now be done, and it will be well to note that the information now given will be needed when we come to consider magneto working.

CHAPTER III.

MAGNETIC FIELDS: CONDENSER.

19. **Electricity and Magnetism—Magnetic Field.**—It is already evident to the reader that electricity and magnetism are intimately connected in some way. We have seen, for example, that an electric current in the primary coil (fig. 12) produces strong magnetism in the iron core. The current does not itself reach the iron core: the iron is simply *in the neighbourhood* of the current. Experience has shown that the space near any current is in a condition to magnetize iron or steel. The technical way of putting it is to say that a magnetic field is produced by an electric current.

The meaning of this term is shown in fig. 14, which is a rough drawing of the result of the following experiment. A bar of magnetized steel is placed on the table, and a sheet of cardboard put over it. On this is evenly dusted a quantity of iron filings, and then the cardboard is gently tapped. The filings immediately set themselves in a series of definite and beautiful lines as in fig. 14.

If the magnet be removed, the filings fall back to a confused state as soon as the cardboard is tapped, so that it is only in the neighbourhood of the magnet that these lines are formed. The "lines" are known as "lines of magnetic force," and they constitute what is called a "magnetic field." It is most interesting to observe how these magnetic lines actually do the work attributed to the magnet. For example, when a piece of iron is "attracted'

by a magnet, the attraction is accomplished by these lines. They may conveniently be regarded as servants of the magnet. They seize the iron, and then, by shortening themselves, bring the iron to the magnet.

20. **Electromagnets.**—A magnetized bar of hard steel like that used in the experiment is a permanent magnet: it retains its magnetism and its magnetic field. Suppose now we take a bar of soft iron. If tested, it proves to be free from magnetism. Put

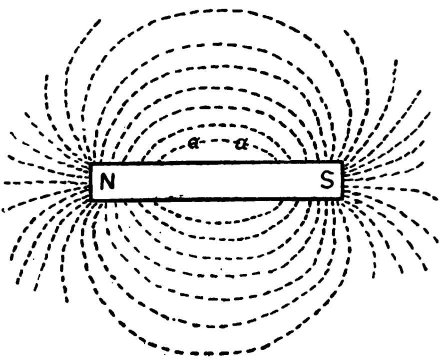


Fig. 14.—Magnetic field round a straight magnet.

this bar inside a coil of wire through which a current of electricity is flowing, and the soft iron is immediately magnetized. Its ends or poles attract iron, and, if tested by filings, it is found to have a magnetic field round it, just like the steel permanent magnet. But the magnetism of the soft iron is dependent on the current. It vanishes as soon as the electric current is stopped.

A magnet like this, dependent on a current, is called an electromagnet. Evidently it gives us the

chance of making a magnet when we like, or of destroying the magnetism when we wish. All that is requisite is to start or to stop the current required.

These statements briefly summarize the main facts about electric currents and magnetism. We may put them in one sentence as far as they bear on the coil question. *When electricity moves*, it produces magnetic effects round about it. It magnetizes iron, it sets up a magnetic field.

21. **Growth and Collapse of a Magnetic Field.**—When a straight bar is magnetized by a current, the magnetic field does not spring into existence instantaneously. It grows little by little, the field spreading out from the magnet as ripples spread out from a stone dropped in water. The "lines" move sideways. The motion is exceedingly rapid, but not too rapid to be traced.

Suppose the current started at a definite time, say exactly one o'clock. In a fraction of a second it may have produced two or three lines of force, the outermost reaching, say, an inch or two from the bar. In the next fraction other lines have started, and spread themselves like ripples, pushing the earlier lines away. Each line gets longer, its ends on the poles of the magnet, its middle spreading further out. This process goes on till the current can produce no more, although a stronger current might do so.

The process is a growth.

Now suppose the current stopped at a definite time. The magnetic field does not disappear instantaneously. It vanishes by decay. The "lines" move sideways back towards the magnet. The nearest ones disappear, collapsing on the iron. The others follow, one by one, until all have collapsed there.

Keeping this in mind, the reader is now able to

give a real meaning to the following statement. When an electric current passes through the primary winding of a sparking coil, a magnetic field spreads out from the iron core. When the current is stopped, the magnetic field falls back again on the core. In the sparking coil, magnetic lines must be continually passing outwards and inwards through the secondary coil.

We have now to learn the striking fact that a moving magnetic field has a great influence on electricity.

22. **Electrical Effect of a Moving Magnetic Field.**—Whenever these magnetic lines move across a conductor, they exercise pressure on the electricity in that conductor, pushing it in a given direction and causing one end to become positive, the other negative. Indeed this is the basis of the dynamo, which consists of a magnet with a coil or coils of wire rotating between the poles. Keeping this in mind, and applying it to the secondary winding of the ignition or sparking coil, we see that the magnetic lines continually moving outwards through it (when the current starts in the primary) and the same lines as they fall inwards (when the primary current stops) will set up electric pressure in every convolution of the wire. Now there are many thousands of convolutions of wire in the secondary (see par. 16, page 27), and the effect of one is added to that of another. Hence there arises a very high voltage in the secondary coil.

Notice that the outward spread of the magnetic ripples thrusts electricity in one direction, and that the inward collapse reverses the thrust. Hence each end of the secondary winding becomes alternately positive and negative.

23. **"Trembler" Coil.**—This is the more generally used form, and is similar to a non-trembler coil in the main, but it has an additional contrivance

for automatically and rapidly making and breaking the circuit. In this way, a series of secondary sparks may be obtained during each completion of the primary circuit by the contact breaker.

Fig. 15 is a diagram of such a coil, drawn to make the action as clear as possible. Fig. 16 is a rough sectional drawing, giving an idea of the form which the trembler takes in the coils used on cars. As far as possible the lettering is the same for corresponding parts as in figs. 10 and 11.

Taking fig. 15 first. There is the primary coil *P*; the secondary coil *S*; the iron core *I C*; and

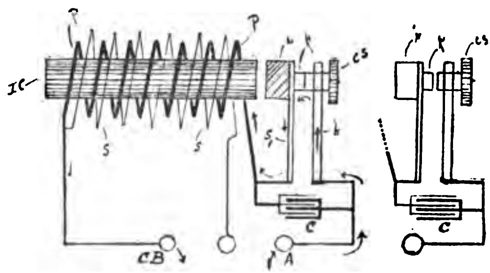


Fig. 15.—Diagram of trembler coil.

the condenser *C*. These are much the same as in the non-trembler, and serve the same purpose. In this figure the trembler consists of a flat spring s_1 which is rigidly fixed at its bottom end and free to vibrate at its upper end. Fastened to it on one face is an iron boss *i*; on the other face is a tip of stout platinum wire *p*.

Pressing against this platinum wire is the end of a contact screw *c s*, which works in the brass standard *b*. The contact screw *c s* has a platinum tip at its end where it presses on *p*, so that at this contact point, platinum touches platinum. It is at

this point that the trembler contact is broken. Leaving the condenser out of account for the moment, it is easy to follow the action. The current flows in at the terminal marked *A*, passes up through the brass standard *b*, across the platinum contact, down the flat spring s_1 into and through the primary coil. It then passes out by the terminal marked *C B*, going from this through the wipe contact or commutator in the usual way.

Consider now what will happen. This primary current magnetizes the iron core, which therefore attracts the iron boss *i*. This magnetic attraction is opposed to the elastic strength of the spring s_1, and, as soon as it is strong enough, it drags the iron boss and spring forward. The forward movement of the spring breaks the primary circuit, because it carries the platinum tip *p* away from the end of the contact screw *c s*. Thus a gap is formed between *p* and *c s*, as is shown in the auxiliary sketch fig. 15*a*. The primary circuit is broken.

The primary current therefore ceases to flow, and the magnetism disappears. The magnetic pull immediately vanishes, the spring s_1 jumps back to its vertical position and re-establishes contact between *p* and *c s*. The primary current starts once more and the cycle of events is repeated.

The explanation here given involves so many words that the student may get confused. It is good, therefore, to put the cycle of actions more succinctly.

(*a*) Primary current flows and magnetizes core.

(*b*) Magnetized core attracts *i* and breaks primary circuit.

(*c*) Magnetic attraction therefore ceases and spring re-establishes contact.

(*d*) Primary circuit is complete and cycle begins again.

Owing to the rapidity of action the spring s_1 is kept "trembling" while joined to the battery.

24. **Hammer Form of Trembler.**—Having mastered these explanations, it is easy to understand the forms more usually employed on coils used for ignition, fig. 16.

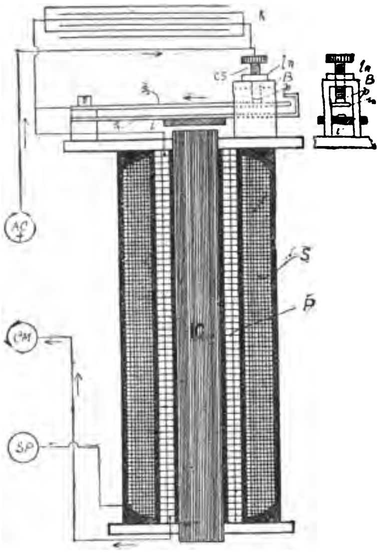


Fig. 16.—Hammer form of trembler.

The spring s_1 carries an iron boss *i* as before, but the platinum tip *p* is fixed on another spring s_2. The first spring has its end bent up and then backward so as to overlap s_2 a little way. The contact screw *c s* works through the top of a metallic bridge *B*.

This construction offers some advantages over the simpler form shown in fig. 15.

When the iron core is magnetized, it attracts the boss *i* and drags it (along with s_1) downwards. As they move downwards the attraction increases and they move with increasing velocity. At a certain point in their downward movement, the end of s_1 is brought into sharp contact with that of s_2, knocking it downwards with great *suddenness*. Seeing that s_2 carries the contact platinum tip *p*, it is evident that the two platinum contacts will be violently separated and the primary current stopped by a very decisive action.

The difference between this and the simpler spring of fig. 15 lies in this:—In the simpler case, separation of the contacts is brought about when the magnetic attraction is greater than the rigidity of the spring. In the trembler of fig. 16 the rigidity of the spring is overcome by the joint effect of magnetic attraction and the momentum of the spring s_1, which is moving with considerable speed when it strikes s_2.

It will be understood that in the trembler coil, the primary current flows only while the contact breaker is completing the circuit. But although this is a very short time, it is long enough for the trembler to perform several vibrations. In this way several sparks are produced at the spark gap for each contact of the commutator.

There are many varieties of trembler made. The aim has been to secure rapid make and break without noise. In one form (Castle coil) the end of the armature spring strikes against indiarubber rings fixed on the screw which it commonly touches. Fig. 17 gives a view of this. In another form (Fuller) the vibrator consists of two wires tightly stretched, which can give a very rapid vibration.

It only remains to say that the effect due to the

"break" of the primary current is much greater than that to its "make." In other words, the effect of the contraction and disappearance of the magnetic field is much greater than that due to the production and expansion of it. This arises from a far greater rapidity of motion on demagnetization. The condenser *K*, seen in figs. 11, 15, and 16, whose action will be explained later, is used to hasten this process of dying away, and it generally increases the electric pressure produced in the secondary coil

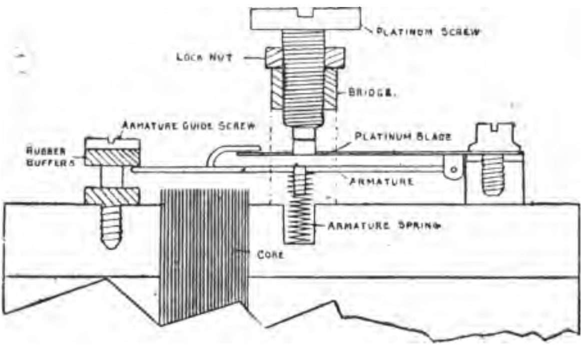


Fig. 17.—"Castle" trembler.

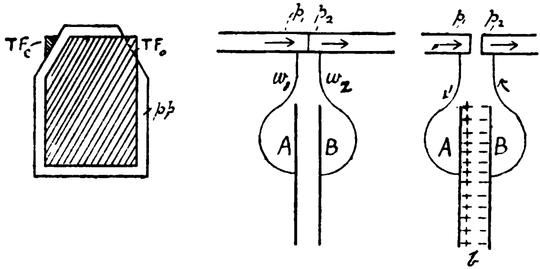
some six or seven times. The general result of this inequality of effect at the "make" and at the "break" is to suppress the spark which might be expected at the "make," and we may regard the useful effect in the secondary as being due solely to the disappearance of the magnetic field.

25. **The Condenser.**—The action of this apparatus is not easy to explain to a reader who is not familiar with electric affairs, but the following account will make it more or less clear.

Notice first how the condenser is made.

Theoretically, it is a couple of conducting sheets or plates placed near each other. In other words, it is formed of two conductors separated by a non-conductor. But in order to get the effect of large sheets in a limited space, it is usual to interleave smaller sheets, connecting alternate ones together; they are prevented from touching by one or more sheets of mica or paraffined paper.

Condensers for coils are made of sheets of tinfoil interleaved with insulating sheets of paper which has been soaked in melted paraffin wax. After being squeezed into a fairly compact mass, the



Figs. 18, 19*a*, 19*b*. – Condenser of coil.

tinfoil sheets are connected together so as to make them electrically equivalent to two sheets. The first, third, fifth and other odd numbers are joined to form one plate. The second, fourth, sixth and other even numbers are joined to form another plate. Fig. 18 gives an idea of the method of forming. Sheets of paraffined paper *p p* are cut to the shape shown. Then sheets of tinfoil are placed with their points projecting alternately. $T\ F_o$ is the representation of the *odd* numbers; $T\ F_e$ for the even numbers. It will assist us in explaining the action if we represent the condenser

by two parallel lines, as in fig. 19, or by two independent interleaved sets of lines, as in figs. 15 or 16.

26. **Electric Inertia.**—To understand the action of a condenser, notice two things as a preliminary. First, the tinfoil coatings are joined to the two sides of the contact at the trembler. When the contact points are touching, the condenser is not in action, and it is of no use. When the points are separated by the pull of the magnetized core, the condenser comes into play.

Secondly, an electric current cannot be stopped instantly. It has momentum, and when an obstacle is put in its way the momentum carries the current on for some time (though a short one). Consequently when the trembler points are opened, the air gap does not stop the current which was flowing. The battery pressure is too low to send electricity across such an air gap, but the momentum pressure is enormous, and causes the electricity to flow on still, dying down with *comparative* slowness. The case is exactly similar to that of a moving motor car which meets with an obstacle—say a wall. The car and the wall are both smashed by car momentum, not by the power of the engines.

In the electrical case, momentum leads to a spark at the opening of the trembler contact points, which means that the current does not stop as quickly as was intended. This continuance is objectionable because it *delays* the fading away of the magnetic field, and therefore diminishes the pressure produced in the secondary. If the primary current could be stopped *at once*, the magnetic field would shrink through the secondary coil with the utmost rapidity, and so produce a very great sparking pressure.

Now the condenser is introduced to absorb the momentum energy of the current, and so bring it to

rest more quickly. Figs. 19 *a* and *b* show how it does this. The condenser plates (two parallel straight lines *A B*) are connected to the trembler contact points p_1 p_2 by wires w_1 w_2. A current is flowing across the contacts as shown by the arrows; on the left, towards the contact; on the right, away from it. The condenser plates are in their natural electrical state, and take no part in the action while the points are touching.

Now let the contacts open: there is at once formed a non-conducting air path of great resistance between p_1 and p_2. At the same moment there is connection by wire to the condenser plates *A* and *B*. The moving current, therefore, must either spend its momentum in darting across the air gap, or it must urge the electricity to flow to *A*.

The latter is the actual course followed. The electricity which is moving towards p_1 is carried to *A*, where the pressure rises enormously. The plate *B* also gets electrified, for the momentum of the current receding from p_2 causes some of the electricity in *B* to follow. Hence *B* gets a kind of negative charge by withdrawal of some of its natural store of electricity. The condition of the two plates immediately after the contact points p_1 and p_2 have separated can therefore be represented by fig. 19 *b*. Thus the presence of the two connected plates of the condenser has diverted the moving electricity from the air gap, and has thus prevented the formation of a spark there. But there is a further beneficial action. As the plates *A* and *B* get charged by the arrival of more and more electricity at one and the departure from the other, the electrical pressure on the plates increases.

The first portions which arrive at *A* oppose the coming of further quantities; they set up an electrical pressure opposing the flow. Hence the

momentum of the on-coming current is destroyed by the opposing electric force set up.

The case is analogous to the stopping of a train. It can run full speed into a station, and be stopped in two ways: first, by running into hard solid buffers (this is similar to an electric current running against an air gap). Secondly, by running against long spring buffers (this is similar to an electric current running into a condenser).

When the train runs into hard blocks, it is not thereby stopped at once. It goes on moving by momentum in a quite uncontrolled way, and there may be two or three seconds before the motion is actually stopped; the buffers breaking, the train smashing, &c., &c. The momentum breaks down the obstacle, just as electric momentum breaks down the obstacle offered by an air gap when the platinum points in a trembler are opened.

When the train runs into long spring buffers, it is stopped much sooner, and in a much safer way than in the first case. Its momentum energy is spent in compressing the springs, and as the spring is compressed it exerts an *increasing back pressure* tending to stop the train. These effects are comparable to those produced by the condenser in the electrical case. It slows down the moving electricity, and robs it of its momentum quickly and safely.

By its means the time required for stopping the current is very much shortened. It may be reduced to one-sixth or one-seventh its previous value. This means that the magnetic field will disappear so much more quickly, with the result that the spark produced in the secondary may be made (if necessary) six or seven times as long.

27. **Review of Coils, &c.**—The action of a sparking coil is so novel to a beginner that the explanation given will need reading more than

once. It may therefore be useful to sum up the foregoing in a few sentences.

First, the cells are for establishing and maintaining a magnetizing current whenever the primary circuit is completed by the commutator.

The trembler of the induction coil is used to give a series of makes and breaks during the time the commutator completes the circuit. In that way it leads to a fluctuation in the magnetic field. In its turn, this fluctuating magnetic field sets up great electric pressure in the secondary.

The condenser increases the effectiveness of the trembler, by hastening the stoppage of the primary current at the "break," and so quickening the collapse of the magnetic field.

The secondary coil serves as a generator for the spark plug, the electromotive force set up in it being able to burst through the air and fire the electric spark.

We shall now indicate the modifications adopted when the engine has more than one cylinder.

CHAPTER IV.

MULTI-CYLINDER ENGINES AND SYNCHRONOUS IGNITION.

28. **Two-cylinder Engine.**—Fig. 20 shows the connections for this. The coil box contains two independent coils; $C\ M$ is the commutator with two terminals $t_1\ t_2$. Although not necessary, two batteries $B_1\ B_2$ are shown, one acting as a stand-by in case the other goes wrong. This necessitates a two-way switch $T\ S$ by which either B_1 or B_2 can

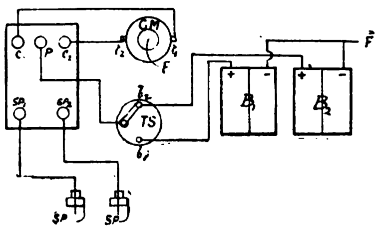


Fig. 20.—Arrangement for two-cylinder engine.

be joined to the P terminal of the coil. As it stands in fig. 20, B_2 is in use, B_1 is cut out. If the arm of $T\ S$ were brought down, B_1 would go into circuit and B_2 go out.

The contact terminals $t_1\ t_2$ on the commutator are set sometimes 180° apart (as in fig. 20), sometimes 90° apart. This is determined by the cranks on the engine shaft and by the aim of the designer.

Fig. 21 reveals the internal connections. The

lettering agrees with that of fig. 20. The terminal P is joined to the tremblers T_1 T_2 of the primary coils P_1 P_2. The other ends of the primaries go respectively to C_1 and C_2. From these wires are taken to the commutator terminals t_1 t_2. The secondaries S_1 S_2 are shown apart for distinctness. It will be noticed that one end of each secondary is periodically connected to the frame because it is joined to an end of its primary and through the terminal C_1 or C_2 and the commutator to the half-speed shaft.

Let us suppose that the rotating arm of the

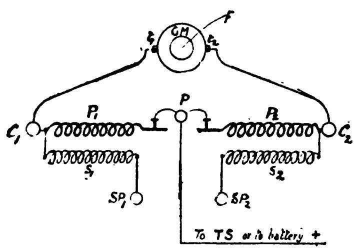


Fig. 21.—Diagram of connections.

commutator is touching t_1, figs. 20 and 21. The current path is as follows:—

From + terminal of B_2 to b_2, through T S to P, through P_1 to C_1 thence to t_1 and commutator arm to frame. From the frame to the negative terminal of B_2. The negative terminals of B_1 and B_2 are both joined to the frame, but as B_1 is disconnected on the other side, no current flows to it.

The current through P_1 causes a series of sparks at S P_1, the trembler T_1 vibrating vigorously while the circuit is closed. When the arm of C M leaves t^1 both coils are cut out till it reaches t_2. This completes the circuit through P_2, C_2 and t_2 instead

of P_1, C_1, and t_1. Consequently it is the secondary S_2 which is then energized, and the sparks occur at $S\ P_2$.

NOTE.—The battery is brought into action twice every revolution, and its exhaustion will come in half the time.

29. **Four Cylinder, Four Coils.**—Fig. 22 will be easily understood after what has been said about the two-coil arrangement. A four-cylinder engine is here worked with four trembler coils, and a four-way commutator, *C M*.

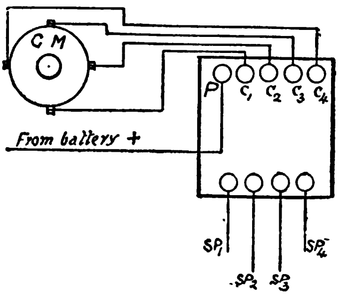


Fig. 22.—Four-coil trembler for four-cylinder engine.

The wire from the positive end of battery runs to *P*, which is a terminal joined to each of the four primary coils, the other ends of which are joined severally to C_1, C_2, C_3, C_4. Through these and the commutator each primary is brought in turn into the circuit, and the secondary of that coil which is in action causes a spark in the corresponding spark-plug. Obviously the contacts in the different primaries will come at intervals of exactly a quarter of a revolution of the half-speed shaft, or at every half revolution of the crank shaft.

It will be understood that the spark at one of

these plugs ought to appear at the same position of its piston as in the other cases, and this cannot be unless the primaries and secondaries are exactly alike. Even then there may be dissymmetry and delay due to one of the tremblers getting a little worn or out of adjustment. It has been proposed, therefore, to use only one coil, as shown in the following paragraph.

30. **Four Cylinder, Single Coil.**—In this

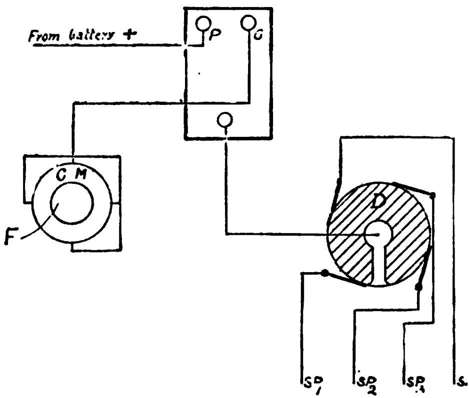


Fig. 23.—Single coil with distributer for four-cylinder engine.

system, fig. 23, only one coil is used. This must be a trembler coil. The commutator has four contacts, but to all intents and purposes they are one. That is, they operate only one primary circuit, but they make contact in this four times for one revolution of the half-speed shaft. This ensures getting the sparks at the right time.

To get the sparks in the right cylinder, a four-way high-tension distributer, *D*, is used. This consists of an insulating disc with a conducting

segment running from centre to circumference. Four brushes touch its edge as shown. The spark current comes to this segment and passes away by the brush which happens to be touched by it at the moment. It is necessary that the contacts should be made by *C M* at the same time as the corresponding brushes touch the segment of *D*. In setting up the arrangement this must be carefully arranged.

As the high pressure of the secondary circuit is felt by the segment and insulating disc *D* at every excitation of the coil, it is necessary that they should be exceedingly well insulated; otherwise leakage is sure to occur, and mis-firing result. This single-coil method of working four cylinders is known as *synchronous ignition*, because it ensures that all the sparks shall occur at a corresponding "time."

31. **Synchronous Ignition and High-tension Distributer.**—It has just been remarked that a high-tension distributer must be well insulated. Yet it is not easy to ensure this completely: a very little moisture may cause some leak.

Such a leak on the distributer may cause non-synchronous firing, for it is a characteristic of such a leak that it is uneven. It may, therefore, lead to an early spark with one brush and not with another.

One way of meeting this is to set the metallic segment on the high-tension distributer to touch the brushes *slightly before* contact is made at the commutator terminals. Leakage over the surface is then abolished, because there is a good conducting path provided as the voltage rises, and there will be no tendency to flow over the disc.

Another way is this. The high-tension distributer brushes shown in fig. 23 are replaced by screw terminals which can be set so as to approach

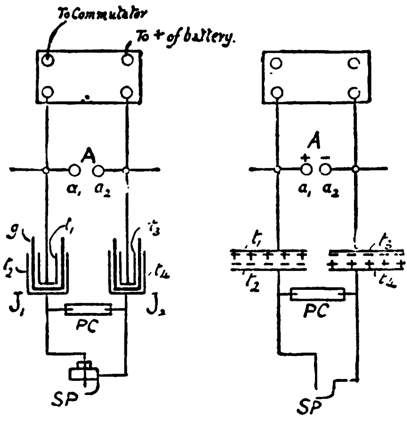
very near the distributer disc but not to touch it. This introduces an air gap in the path of the secondary discharge. As the segment comes round to the screw terminal the voltage is high enough to burst this small air gap as well as that in the spark plug, and no disadvantage follows. But there is this advantage: moisture, &c., cannot cause leakage because it has this air gap in series with it.

32. **Lodge's System of Ignition.**—Some troubles of a high-tension circuit have already been mentioned. They arise chiefly from leakages. Apart from insufficient insulation, or from injury to otherwise good insulation, leakage may occur from the presence of moisture, or from the presence of soot (carbon) deposited between the points of the spark plug. This last fault was more common formerly than it is now, owing to improvements in the design of carburettors and greater skill in using them. When the proportion of petrol vapour and air is not kept within certain limits, there is a chance that there may not be enough air to consume the petrol properly. In such a case, carbon may be deposited on the plug between the points, and provide a partial conducting path between them. When this happens the spark frequently fails. The electricity leaks through the carbon bridge rather than jump across the highly-resisting air.

To get over all these sources of leakage, Sir Oliver Lodge utilizes the fact that leaks, not being very good conductors, require time to convey any fair quantity of electricity. He therefore proposes to create the pressure so suddenly that the leaks have no time to act, the electricity leaps across the air gap before it can be fairly started through the moisture or carbon.

The sketch in fig. 24 illustrates the method. The apparatus includes battery, contact breaker,

and induction coil; as the first two do not differ from the usual arrangement they are not shown in the diagram. The difference begins with the disposal of the wires from the secondary, which are *not* taken to the spark plug but to the inner coatings of two condensers, J_1 J_2. These are of the form known as Leyden jar condensers, and consist of a glass jar g, partly coated with tinfoil



Figs. 24 and 25.—Diagram of Lodge's method of sparking.

on the inside and out. The inner tinfoil t_1, of J_1, is joined to one end of the secondary and also to a small ball a_1 at an auxiliary spark gap A. The inner tinfoil t_3, of J_2, goes to the second end of the secondary, and also to a small ball a_2 at the gap A. The outer coatings t_2 and t_4 are joined to the spark plug $S\ P$ in the usual way, but there is an additional conductor $P\ C$ joined across the wires from t_2 and t_4. It is necessary that this conductor

should be a poor one, that is, have very slight conductivity, and it is for this reason marked *P C* (poor conductor) to emphasize this point. Any poor conductor would do: the one generally used consists of moistened blotting paper contained in a glass tube.

The auxiliary sketch, fig. 25, is for the purpose of making the explanation clearer. Instead of the Leyden jars, each condenser is represented by parallel lines for the tinfoil coating. The glass is omitted. The action is much the same through air and glass, and the omission relieves the diagram.

When the electric pressure is set up in the secondary, one end becomes positive, the other negative. Let us imagine this process to be going on slowly, and also that the left end is the positive. Being connected with this, the ball a_1 and the tinfoil t_1 will become positive: at the same time a_3 and the tinfoil t_3 will become negative. The pressure increases until the air between a_1 and a_3 cannot stand it, a spark then occurs at A which completely discharges the balls and also the tinfoils t_1 and t_3. The + on t_1 and the − on t_3 rush across the gap A and simply neutralize each other. The secondary then acts afresh and recharges them in the same way as at first. Thus there is a succession of sparks at A. The jars are therefore charged and discharged, but it is of importance to note that the charging operation is *comparatively* slow, and the discharging operation very rapid—almost instantaneous. Let us now consider what happens on t_2 and t_4, while t_1 and t_3 are being charged and discharged, keeping in mind that t_2 and t_4 have plenty of both + and — electricity in them. Whilst t_1 is being charged positively, the positive electricity acts on t_2, repelling some of the + in it through P C to t_4. At the same time the negative charge on t_3 repels some of the negative electricity

in t_4 through $P\ C$ to t_2. Thus it comes to pass that *just before a spark occurs* at A, and while t_1 and t_3 are fully charged, as shown in the diagram, opposite charges are *induced* on t_2 and t_4; t_2 is said to have an induced negative charge; t_4 an induced positive charge.

The peculiarity of these induced charges is that they do not unite or flow together, although they are connected by a conductor ($P\ C$). They are kept apart by the strong attraction of the opposite charges on t_1 and t_3.

Now suppose that t_1 and t_3 are discharged by a spark at A. Their charges disappear almost instantaneously, and this means that their constraining influence on t_2 and t_4 goes in the same rapid manner. Thus when the spark occurs at A, the charges on t_2 and t_4 are as it were *set free.* The pressure rises with a bound; they tend to come together with tremendous electrical force. In presence of this *sudden* pressure, the conductor $P\ C$ is too poor to be effective, and the bulk of the charges on t_2 and t_4 burst across the spark gap at $S\ P$ in a sharp hot spark. If there be a deposit of carbon on the plug, it will in like manner be unable to convey this sudden rush, although it might quite easily convey an ordinary discharge.

Evidently there will be a spark at $S\ P$ every time one occurs at A. Sir Oliver Lodge calls the auxiliary spark at A, the A spark; and the other (as at $S\ P$) the B spark. The method was originally worked out, not in connection with ignition processes, but during the investigations which led up to wireless telegraphy.

CHAPTER V.

FAULTS.

It is a common saying that the ignition mechanism gives more trouble to ordinary men than all the other parts put together. This probably arises from the fact that electrical appliances are not understood by most motor men, nor even by all those who put the mechanism on the car. It is easy for such men to make mistakes, because they do not appreciate the importance of the thing done or left undone. To make good electrical contact at one place; to insulate well at another; these and similar jobs are more or less mysterious to many, and it is for their sake that this chapter is written.

All parts of the electrical equipment of a car are liable to some fault. Many of these have been indicated or suggested in passing, but it will be well to bring as many as possible together in this place, if only for convenience of reference. Remedies can be suggested where necessary.

A difficulty confronting a novice is that of knowing how to begin to test for the kind of fault which is troubling him at the time. Apart from experience, it is not easy to say what order should be followed; yet some things are obvious. Sometimes the fault declares itself: for example, back-firing shows that the ignition-gear is too much advanced,* and ought to be retarded. Sometimes it is more or less located: example, the spark fails although

* This is on the assumption that the ignition gear is in fault. It is possible for undue heating of the cylinder to cause back-firing: or for a charcoal deposit on the sparking points to be set glowing by the spark and to glow long enough to do mischief.

the trembler is working vigorously. This proves that the battery and the primary are all right: the fault is in the secondary circuit only. Putting aside cases of this sort, we may take each part of the apparatus one by one, and see what faults are liable to occur, and how testing is to be carried out.

33. **Faults in Accumulators.**—Three kinds of fault are noticeable. (1) Low voltage, which causes sluggish action and mis-firing because the current is less than it ought to be. (2) Weak current, although voltage is right. This causes sluggish action, &c., as in (1), but arises from some fault in the conductivity of the circuit. (3) Small capacity, which causes the cells to collapse before a proper amount of work has been obtained from them.

Testing for these faults is made easier by a knowledge of the behaviour of a cell under varying conditions. Example, the voltage depends on the acid strength, as shown in the following table.

INFLUENCE OF ACID STRENGTH ON VOLTAGE OF FULLY CHARGED CELL.

Density of Dilute Acid.	Per cent. of Pure Acid.	Electric Pressure.	
		For 1 Cell.	For 2 Cells.
1016	2·5 per cent.	1·82 volts	3·64 volts
1032	5·0 ,,	1·86 ,,	3 72 ,,
1050	7·5 ,,	1·90 ,,	3·80 ,,
1068	10·0 ,,	1·93 ,,	3·86 ,,
1106	15 ,,	1·96 ,,	3·92 ,,
1144	20 ,,	1·99 ,,	3·98 ,,
1163	22·5 ,,	2·012 ,,	4·024 ,,
1182	25·0 ,,	2·025 ,,	4·050 ,,
1202	27·5 ,,	2·035 ,,	4·070 ,,
1215	29·0 ,,	2·05 ,,	4·10 ,,
1223	30·0 ,,	2·055 ,,	4·11 ,,
1243	32·5 ,,	2·07 ,,	4·14 ,,
1264	35·0 ,,	2·08 ,,	4·16 ,,
1306	40·0 ,,	2·11 ,,	4·22 ,,

Immediately after charging has ceased the voltage of a cell is fictitiously high (see par. 13). The above table shows the values about 45 minutes after charging has ceased.

1. First fault, low voltage. The way to utilize this table is as follows. A battery of two cells having been charged and put aside, for say 40 minutes, is joined to a voltmeter, as in fig. 26. If the reading is less than 4·0 volts, something is wrong. (*a*) Acid may be too weak. Test by hydrometer, which consists of a float which sinks deeper in light liquids and floats higher in denser liquids. A scale on the stem shows the density, fig. 27. Introduce the tip

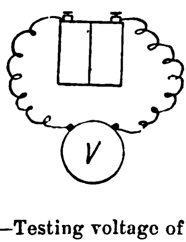


Fig. 26.—Testing voltage of cells.

Fig. 27.—Hydrometer.

of the glass tube into the accumulator, squeeze the ball and then relax it. Acid will flow up and float the hydrometer. Read the figures at the surface of the liquid and compare with the table. Suppose, for example, it reads 1,106. This indicates an acid of 15 per cent., which gives a voltage of about 3·92 volts for two cells.

The question now arises, why is the acid weak? There are four possible causes. (*a*) Insufficient charging. This may very likely be the case if the cell has been over-discharged, and too much sulphate formed. This can generally be told by colour of plates which become too light coloured. Remedied by charging for a longer time and testing again.

(*b*) Acid may have been spilt and replaced by water.

(*c*) Internal short circuit; either because plates have buckled and touched each other, or because plugs of active material have fallen off plates and joined across.

Careful examination by eye will generally show if (*c*) is the fault. A buckled plate or a fallen plug can be seen. Remedy: remove plates and straighten them if buckled, or remove plug if necessary.

If faults (*a*) and (*c*) are absent, and the plates have the full colour of charged plates, the acid weakness is probably due to replacing spilt acid by water. Remedy: pour out liquid and replace by fresh acid, 1 to 5.

It sometimes happens that the voltage of a cell is too high even an hour or two after charging. Acid is probably too strong. This is objectionable because it corrodes the active material (see par. 13), and also because the high pressure resulting causes the coil to act in a lively way for a little while and then become sluggish.

Caution. A careless worker will imagine that the differences of voltage are not very large, and that it is not easy to read them. This is true for many of the cheap instruments. But every instrument can be made more useful by care and by watching its behaviour under different conditions. In reading, let the eye run along the index as it

does in looking along a rifle barrel; much better observations can be taken in this way.

2. Second Fault, weak current, voltage right, trembler won't vibrate. This may be due to bad conditions of primary circuit, either internal or external. Latter will be treated lower down. Internal faults may be :—(*a*) excessive corrosion of positives, causing one positive plate to be detached from its lug; (*b*) sulphate unreduced, filling pores of plates; (*c*) corrosion of terminals and consequent bad connections.

(*a*) This can be seen by a careful eye. Remedy: replace by fresh positives; repair impossible.

(*b*) Sulphate in pores, or on the surface, may so increase the internal resistance that the current never rises to its normal value. The presence of sulphate in the pores practically makes the cell behave as if it were discharged. The voltage ought to be low, but this is not always the case.

The best test is to watch the voltmeter while a conductor of about 2·5 ohms resistance is also joined to the terminals. This will allow a current of about 1·5 amperes to flow. If the pores are partially stopped the voltage will drop appreciably. If the cell is all right, the voltmeter will move very slightly (say not more than 0·1 volt).

This test depends on the fact that the pressure of a good cell will be maintained even when it is giving a current, while if it be in poor condition or nearly discharged, its pressure falls at once if it be asked to do work.

An easy way of making this test without using voltmeter and ammeter is to join a four-volt lamp to the terminals. A current will flow, and the lamp will glow brightly if all be right, that is if the battery can keep up the pressure. But a cell troubled with sulphate in pores will cause the lamp to glow brightly for the first few seconds, fading

into lesser brilliance during the first or second minute. If the lamp glows well for a minute or so, the cells are in fair order. If faulty, the remedy is to give a longer charge. In some cases the cells may want "nursing"; that is, they must be given extra charges and not asked to do so much work in discharge. A skilled attendant knows how to get rid of obstinate sulphate by use of sodium sulphate solution for the time being, but in most cases it is hardly worth while to do this.

The lamp used in this test ought to be a four-volt lamp, and ought also to be chosen so that it takes not less than 1 ampere, nor more than 2 amperes.

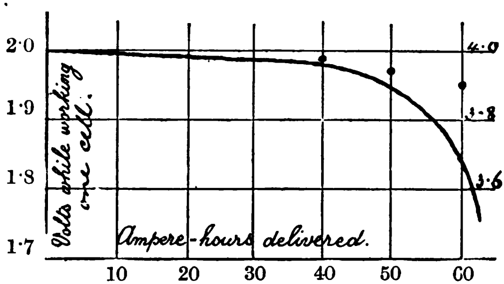


Fig. 23.—Voltage of accumulator during discharge.

(*c*) Corrosion of terminals is more or less obvious, but the nuts ought to be unscrewed and the wires carefully examined. If doubtful, they must be cleaned and the contact surfaces made sure. If nuts stick, care must be taken not to tear them away. They may be freed (sometimes) by holding a hot soldering iron against them for a minute or so. If pliers are used, take care to hold the lower part fast by a second pair. A little paraffin oil often helps to loosen corroded terminals.

In connection with the test for increased internal resistance, under heading (*b*), the reading of volt-

meter and ammeter when delivering a current will be easier to interpret if the reader gets in the habit of using the following curve, fig. 28. It shows the way in which the voltage falls *during the discharge*, that is while the battery is actually delivering a current through the coil.

The battery is supposed to be capable of giving 60 ampere hours before falling to 1·8 volts per cell, or 3·6 volts for two cells (while still running). Points to notice are these. The fall in voltage is very slow indeed till 45 ampere hours have been delivered. The fall then increases at a more rapid rate, and is soon afterwards complete.

Hence, if an accumulator shows 3·96 while working, it still has some hours' run in it. When it falls to 3·90 volts, the collapse may come pretty quickly.

The reader will notice the stress here put on the words "while running." The voltage changes at once if the current be stopped. The little circles above the curve in fig. 28 show the voltage to which the cell will rise if, after the cell is so far discharged, the current be stopped. Thus, after 60 ampere hours, the working voltage is 1·84 for one or 3·68 for two cells, but almost immediately afterwards is down to 1·80 or 3·6. Yet if at the end of 60 ampere hours the current be stopped and the voltmeter read, the pressure (as seen by the circle) rises to 1·95 volts. From this it will be seen that the voltmeter indication, taken when the cell is idle, may be quite misleading.

3. Third Fault in Accumulators, Small Capacity. This may arise because the cells are too small for the current they are asked to supply. The maker can say what the permissible current is. Putting this aside, the causes of small capacity may be (*a*) the use of too strong an acid; (*b*) internal short circuits by buckling of plates or falling out of

material; (*c*) breaking away of plates from lugs; (*d*) sulphate unreduced in last charge; (*e*) local action.

(*a*) Strong acid leads to a loss of capacity by acting directly on the active material and changing it to sulphate without any current flowing. Consequently there is less active material available for current. Strong acid may generally be detected by voltmeter, after a charge, or at any *early* part of the discharge. The reading will be too high, say 4·5 volts for the two cells. Remedy is to substitute weaker acid.

(*b*) These have been mentioned under the first fault.

(*c*) and (*d*) have been mentioned under the second fault.

(*e*) Local action is described in par. 24. There is no remedy for this. It can be avoided by care in the process of manufacture only.

Repasting of Accumulator Plates.—When plugs of active material fall out, it is possible to repaste the plates, but seldom worth while.

To do this, take out the plate, wash away the acid, lay it on a board as far as practicable (taking care to bend the lug as little as possible) and fill the empty holes with a paste made out of litharge and dilute sulphuric acid (1 part acid to 4 parts by volume). Any other plugs which seem loose or pitted may be "faced" up with the paste. Set aside to dry. Then put back in cell, replace cover, and give a good charge. The charge should be started as soon as possible after putting plates back into the acid, a weaker current being used for a minute or two and then a stronger one.

The operation is not likely to be done well by anybody but an expert.

Other faults (like repair of celluloid or ebonite

cases) are remedied by material which can be obtained of the dealers.

34. **Faults in Dry Cells.**—The chief are: loss of capacity by local action (see par. 24); failure of connections by corrosion; and liability to polarization.

Dry cells are practically sealed, and the user is not in a position to remedy any faults. When a serious fault arises, the battery must be replaced by a new one. The sealed condition not only prevents loss of acid or of water, it throws the user back on experiment. There are two tests which serve to reveal the internal condition.

1st. Take the voltage, especially at the end of a run. Serious and threatening polarization can then be easily detected. When the electric pressure is below 1·1 volt per cell, the end is not far off.

2nd. Take a specially strong current for a few *seconds*, say 10 to 15 amperes. The behaviour of the ammeter index will show whether the cells are breaking down under this. In De Dion cars, a new battery ought to be obtained if the old one gives only about 5 amperes when joined to the ammeter. The cause of discharge of dry cells has not received the same attention as that of accumulators, so that not nearly so much information can be given about them.

35. **Faults in the Commutator.**—The moving part may not make good contact firstly, at the circumference, secondly at the half-speed shaft.

This may arise from dirt or insufficient pressure. Remedy: take to pieces and clean the contacts, dealing especially with grease.

Where springs are used it is often necessary to readjust them so as to bring their pressure up to its normal value.

In some forms a film of oil may get between half-speed shaft and the conductor segment of the

commutator. A spring contact can be arranged if necessary.

36. **Faults of Conductivity in Primary Circuit.**—These may be of two kinds: first, bad connection at terminals, &c.; second, a broken or corroded wire.

First fault. Where wires are joined to terminals, there may be several faults. To make the connection, insulation has to be stripped from the end of the wire, and a learner is apt to fall into one or other of two errors. He may cut away the insulation for too great or too small a length.

If too small a length, there is not sufficient bare wire to go round the screw; some of the still covered wire has to be used, and the nut grips down on this insulated part.

If too great a length is exposed, the projecting bare part may touch the frame and cause a short circuit, with speedy collapse of battery.

Remedy is to see that the contact is made truly by bare wire, that no more is exposed than is needed to secure a grip on the bare wire.

Some attention ought to be given to the wire where it leaves a terminal. It is frequently loosely laid, although gripped hard at the end. Then vibration of the loose part slowly breaks it off by the joint.

Other faults are due to dirt getting in between wire and terminal, either by corrosion or by nut working loose, or in any other way. These faults can often be detected by the eye or a touch of the fingers. But some are not so easy to see, and must be tested for as below.

Second fault: a broken or corroded wire. This fault can be seen by even a cursory examination if the insulating covering of the wire is also destroyed. But if, as sometimes happens, the wire is broken while the insulation is intact, it is difficult to localize

the break. Detection is sometimes possible by cautious bending of the wire; if there is no break, the wire bends with a gentle curvature; if there is a break, it is betrayed by the angularity displayed there.

The following method of testing faults in conductivity is quite reliable. The idea is to make the circuit complete (except for the break) and to bridge each part of the circuit in turn by a length of extra wire. The moment this extra wire bridges the faulty conductor the trembler will work; but no

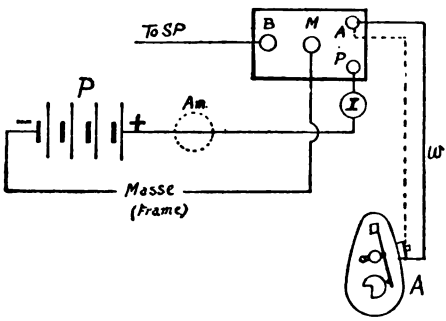


Fig. 29.—Testing for a broken conductor.

current will flow till the faulty wire is thus replaced by the new one. It is advantageous to put an ammeter in circuit, though the trembler can be used as an index.

The method is best carried out in the following way. First see that the commutator is making contact; if not, turn the engine shaft until contact is established with the blade. The switch must also be "on." Now take a piece of wire, and join it in parallel with one part of the circuit. Fig. 29 illustrates the method. It is a diagram of one form

of De Dion winding, but any other would do as well. The commutator or contact breaker blade is supposed to be making a fixed contact; if necessary the blade must be held down. Suppose there is a break in the wire marked *w* fig. 29. Then no current flows. Now let the auxiliary wire shown dotted be made to touch the two terminals connected together by *w*. Evidently the new wire provides a path between the parts where the fault occurs; the circuit will be complete and the trembler will act. If *w* is all right, the new wire makes no difference with regard to the fault, but, in turn, it is made to bridge the switch, the commutator, the ammeter, and each of the wires, till the action of the trembler, or the ammeter needle, tells that the fault is localized. When thus found, the faulty wire must be replaced by a new one.

In this diagram, the letters are the initials of French words and are given to help those who may have to deal with old equipments.

P is the *pile* (or battery); *I* is the *interrupter* (or switch); *A* is either the *allumeur* (or contact breaker) or else the coil terminal joined to it; *M* is the coil terminal which is joined to *masse* (or frame); *B* is the coil terminal joined to the *bougie*, or spark plug.

By proceeding in the way described, a fault in circuit must be found. It does not take much time to make the test; less time than it takes to read about it. There is the slight chance of breaks in two different parts of the circuit. In this rare case the above test will not discover the fault. The best way is to join two wires to an ammeter and connect one of them to the negative terminal of the battery and keep it on during the whole test. The second wire from the ammeter is now taken touched successively on the metal points in the circuit, going round from the positive end of the cells.

Thus the first contact will be on the near end of the switch. If a current flows, the wire from + to *S* is right. If no current, that wire is wrong and must be repaired.

Next touch the far end of *S*, then *P*, *A*, and the contact breaker, then *M*. Proceeding like this, it is always easy to find out the weak parts of the circuit, however many; the conditions being that each fault must be put right as it is discovered before proceeding to any of the others.

37. **Faults in Coil.**—The most usual is want of adjustment at the trembler. The points requiring attention are at the trembler itself. Its contact points get partially frittered together; or they wear away. Readjust. If they are uneven, touch them with a fine file. In adjusting, screw down until sufficient contact is obtained without limiting the play of spring too much. Allow the hammer spring to move about one-thirtieth of an inch before striking the other. After adjusting properly, see that contact screw is locked.

The connection to condenser may be faulty. This is at once shown by fluffy sparks at the trembler contacts. The condenser cannot absorb the spark, and it passes across the break. Remedy is to make the connections to condenser quite sound.

The condenser may be broken down by internal sparking. This may lead to fluffy spark at trembler points, or it may short circuit them. In either case the coil will want repairing by maker.

CHAPTER VI.

MAGNETO METHODS OF IGNITION.

Introduction.—There are many forms of magneto machines. The method of using them is also somewhat varied—not simply as between high tension and low tension, but even in respect of high-tension machines alone. Yet this need not dis-

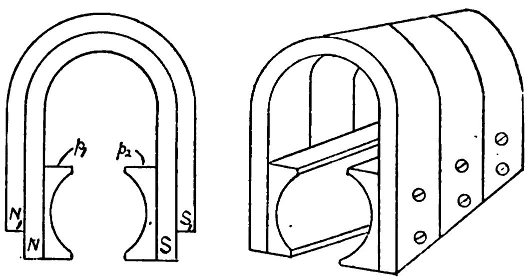


Fig. 30—Ordinary form of magnet.

courage the student, for they are all fundamentally alike. The differences generally refer to the winding of the coil and the method of making connection between its ends and the spark plugs. Almost all of them have the same magnetic arrangements, and, as this is the part which presents most difficulty to the student or user, we shall first explain this part at considerable length.

All forms of magneto have a permanent magnet with a permanent magnetic field: they also have an armature consisting of a coil wound on an iron core

which is arranged to rotate between the poles of the magnet.* It will save time to describe these common features once for all.

38. **Construction of a Magneto.**—The common form of magnet is shown in fig. 30. *N S* are the poles; p_1 p_2 are the pole pieces. As seen in fig. 30 the magnet is built up of three narrower bars bent into the required shape. In many cases three other steel bars are placed over the first, as seen in N_1 S_1, fig. 30. In some machines four or more bars are used instead of the three here shown.

The pole pieces are of soft iron and are nicely bored to receive the armature core, fig. 31. The

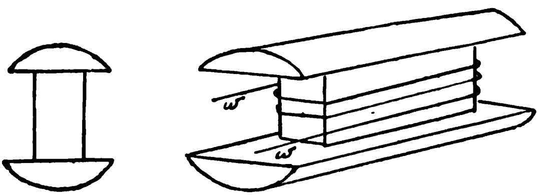


Fig. 31.—Armature core.

shape is sometimes described as being like a shuttle, or like the letter H. In end view it is something like a dumb-bell, on its neck is wound a coil of wire. The coil is here represented by three turns of wire *w w*; as we shall see, many hundreds are often employed.

The outer face of the armature core is turned in the lathe to allow it free rotation between the pole pieces, the clearness between the one and the other being very small; generally about one-twentieth of an inch.

Notice the difference in material. The magnet

* The Simms-Bosch magneto is the only exception.

is made of steel, the pole pieces and armature core are made of soft iron. The core is sometimes more or less laminated, that is built up of sheet iron,

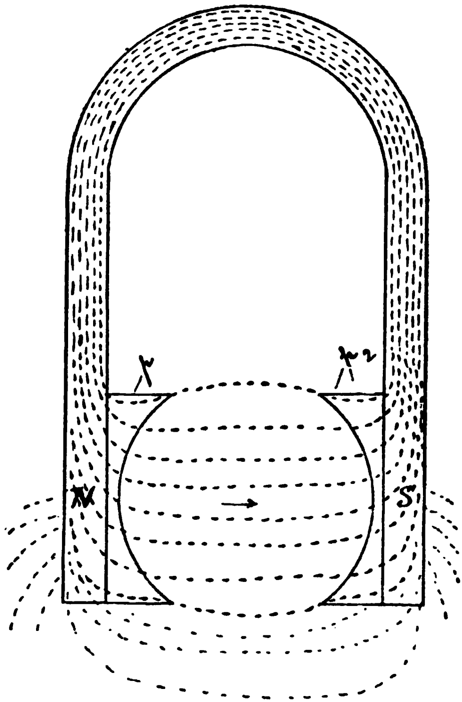


Fig. 32.—Field of magnet: pole pieces present, armature core absent.

each piece being shaped like the end view, fig. 31. The sheets are placed against each other with a thin varnish between to act as a slight insulator.

This lamination and insulation are to prevent eddy currents.

The steel magnet is hardened by heating it and then cooling very rapidly by plunging into water or oil. This is done to obtain magnetic permanence. Hard steel retains magnetism, differing in that respect from soft iron.

To magnetize the steel bars a coil of wire is slipped temporarily over one limb; or better still a

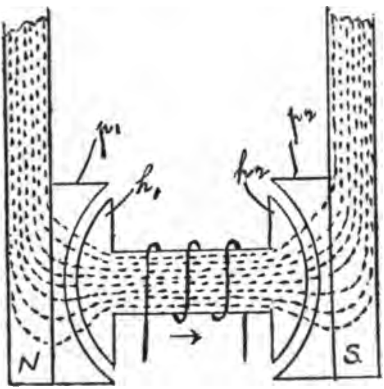


Fig. 33.—Field after inserting armature core.

separate coil over each. These are connected to each other and to a strong battery for a moment, so as to flash a strong magnetizing electric current through them. With proper arrangements the steel is magnetized to a high degree of intensity.

There is another way of magnetizing the horseshoe, namely, by bringing the ends of its two limbs on to the poles of a specially strong electromagnet, whose soft iron core is magnetized as intensely as

possible. If the steel be good, it will retain the degree of magnetism for a very long time, though there is a slight tendency for it to decay. This tendency becomes more marked under the strong vibration of a car, but by proper hardening and by appropriate design of pole pieces and of armature core, the magnetization will be retained at a useful intensity for many years.

These considerations about permanence do not

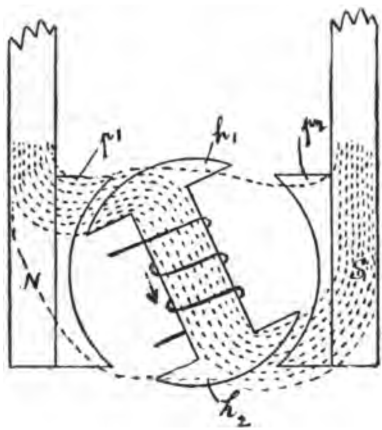


Fig. 34.—Distortion of field by rotating armature.

affect the pole pieces and the armature core, which are made of soft iron.

While it is requisite that there should be a permanent magnetic field or flux* between the poles of the steel magnet, it is equally requisite that the armature (iron) core should either take up the lines or yield them with equal readiness, and soft iron is the only material which will do this.

* Read pars. 19, 20, 21 and 22 once more.

Many movements of the magnetic flux are required in the armature core and in the pole pieces, as we shall see. Indeed this is such an important part of the working of the magneto that the student cannot give too much attention to it.

39. **Action of the Armature Core.**—The shape of the magnetic field of the magneto is shown in figs. 32 to 36. The clue to these figures is found in the fact that the "lines" of magnetic force find

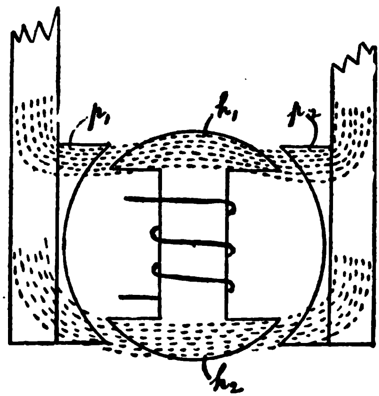


Fig. 35.—Removal of lines from centre of core.

two materials in their way, namely, air and iron, and they establish themselves more easily through the iron, even though that involves a longer and a distorted path. In fig. 32 the iron armature core is absent, and the lines are fairly evenly spread over the whole air space.* In fig. 33 the core is inserted

* The student will notice that the lines are found not simply in the air: they run round the steel. As a matter of fact they are continuous lines, having neither beginning nor end.

and the lines have left the upper and lower parts to crowd into the iron. Remembering that the lines move through the air sideways like ripples, it is easy to see that in the change from fig. 32 to fig. 33, the lines must have moved through the wire wound on the core (three turns of which are shown).

As the armature rotates, the iron carries the lines or most of them along with it, until a critical point is reached, figs. 34 to 36. To follow the action

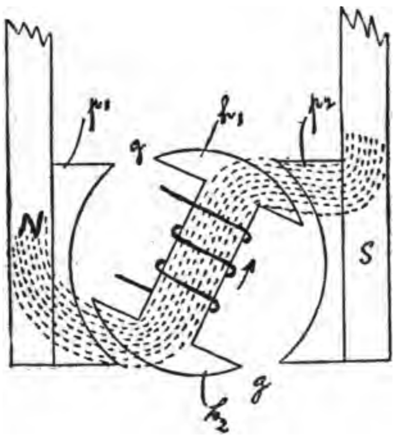


Fig. 36.—Lines re-inserted in central core but reversed in direction.

properly it is necessary to notice the direction of the lines, which is always taken to be along the line, reckoning from the North Pole, *N*, and towards the South Pole, *S*. Arrows show the direction of the lines in each diagram. To make it easy to distinguish, one pole piece is labelled p_1, the other p_2. In the same way, one head of the dumb-bell

core is labelled h_1, the other h_2. These letters will be retained as the core rotates.

In fig. 34 the lines have largely followed the armature to get the advantage of an iron path. A few, however, have left the neck and pass both other routes. Two of these are shown, one at the top and the other at the bottom of the diagram. In fig. 35 they have all passed out of the neck and are stretching from pole to pole through the heads. In getting to the new position they have "rippled" through the coil and set up an electric pressure.

In fig. 36 they have been put into the neck again *but in the reverse sense.* They enter now at h_2 and pass out at h_1 (see arrow), which is contrary to the direction in fig. 34.

If we followed the rotation further we should reproduce fig. 34, *with the core and coil reversed*, so that it need not be drawn. The lines would all be in the neck again, as at first, though they would be passing through the coil in the new sense.

In all these changes of the magnetic lines we have disturbance of the electricity in the wire, thrusting it in one direction, setting up a certain voltage, and causing one end of the coil to be positive and the other negative, like the terminals of a battery.

We may notice that if the armature rotation be continued through the second half of a revolution, we should find the same effects as in the first half, but the magnetic and the electric action would be reversed in direction. Thus in the second half of a revolution the voltage produced in the coil is of the same value as before, but the end which was positive is now negative; that which was negative is now positive.

40. **Measurement of Magnetic Changes.**—It has not hitherto been possible to get definite information about the change of magnetic lines in a magneto

armature, nor to find the electric pressure as the armature rotated from point to point. A great deal has been written about the matter, but no one has been able to give figures. The author has therefore made experiments on these points, and gives the results in the following tables, &c. The experiments were made on a low tension magneto of the Castle type.

In the first set of experiments the number of magnetic lines passing through the centre or neck of the core was measured. The first measurement was made when the core stood as in fig. 33; the second after rotating the armature 6°; the third after 12°, and so on. The following table gives the chief results in figures, more details can be gathered from the curve in fig. 37.

The number of magnetic lines passing through the neck of the core (and therefore through the coil) was measured in various positions, with the following results:—

Position of Core.	Lines passing through Coil.	Number taken out.
1. As in fig. 33	70,000	—
2. After rotating 20°	68,200	1,800
3. After rotating 45°	60,000	10,000
4. After rotating 60°	52,000	18,000
5. After rotating 84°	31,200	38,800
6. After rotating 92°	20,800 reversed lines	99,800

From this table, as from fig. 37, many important points can be deduced. As the armature rotates, the lines are *slowly* taken out, the rate of removal increasing very much, about 60° from starting. This increase goes on as 90° is approached, and as 90° is passed the whole of the remaining lines are removed and 20,800 lines are put through from the other side.

The same thing can be put in another way. In

the first 6° rotation the magnetic change amounted to 200 lines only.

In the *first twelve degrees* rotation the lines removed amounted only to 800.

Now contrast with this the magnetic change when nearly 90° away from the start.

In the 8° rotation from 84° to 92°, the magnetic changes amounted to 52,000 lines, or say 100 times as much as in the earlier cases for the same degree of rotation.

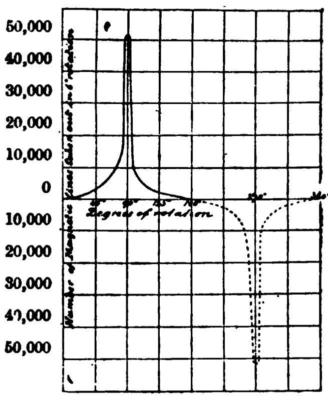


Fig. 37.—Rate at which magnetic lines through armature coil are changing.

41. **Explanation of Magnetic Curve.**—The meaning of this curve is simple. The figures written horizontally (0°, 45°, 90°, &c.) give the degrees of rotation of the armature from the zero position shown in fig. 33. The height of the curve shows the rate at which magnetic lines are being removed from the armature and coil. The actual magnetic change thus shown is important, because it shows us at once the way in which the electrical pressure

or voltage varies. The rate of magnetic change is a maximum at 90°, *therefore* the electric pressure will be a maximum at that point, and so on.

The general results may be gathered together as follows:—

During each rotation of the armature core, an electric pressure is produced in the coil owing to the movement of magnetic ripples through it. This pressure (and the consequent current) flows in one direction for half a revolution, and then in the reverse. The zero point or position of reversal is that shown in fig. 33. (As the core is in this position twice during each revolution there are two reversals in each revolution.)

But the value of the current is not uniform during each revolution: it begins at a low value and runs up to a maximum (about 90° from zero), then falls away to zero at the end of half a revolution where it reverses and repeats the variation. The reversal is shown in fig. 37 by measuring downwards instead of upwards (see dotted half).

Now it is a matter of importance to a manufacturer of magnetos to make the maximum as great as possible. He must know whereabouts it comes, for it is at this moment that he will be able to get the best spark. Consequently he finds it out by experimental trial, and then arranges so that a cam shall act at this time, and allow the armature coil to be joined to the spark points or other apparatus.

In practice, the points of maximum action do not occur exactly at the places shown in fig. 37. The numbers there included were obtained during slow and gentle rotation. In practice, the speed is great and vibration excessive, and both these have an effect on the magnetic changes. They make the maximum slightly less, and shift it somewhat away from the 90°. Hence the time of maximum must

be found by experiment. A further statement is given in the last paragraph of the book.

42. **Armature Coil.**—To get more space for wire, the armature spindle is not fixed to the core directly, but to "end plates" *e p* screwed to the ends of the core, as seen in fig. 38. The spindle is often hollow, and the live end of the wire can then be brought along inside and attached to a block or rod which serves as a contact stud so as to get connection to outside. Fixed connections are not possible (except on the Simms-Bosch principle), and various contrivances are used to lead the current in and out.

Rubbing contacts of a "brush" type are sometimes

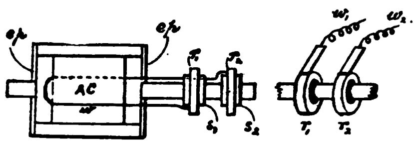


Fig. 33.—Contact with armature coil.

used. These are suggested in fig. 38. The armature coil is shown by one turn only. Two metal rings r, r_2 are carried by insulating bushes or sleeves s_1 s_2 fixed to the shaft. The ends of the coil are taken to the rings, one end passing directly to the ring r_1, the other going to r_2 through a hole in the first insulating sleeve s_1. Thus the rings become equivalent to the ends of the armature coil, and it is only necessary to have fixed brushes rubbing on them to obtain continuous contact of external wires w_1 w_2 with the ends of the internal coil. The Eisemann magneto used this method till recently.

It was soon seen that one ring and one brush would suffice, for one end of the armature coil can

be fastened to the iron core, and thus be joined through the shaft and bearings to the body of the machine. Connection to this end is obtained by joining an external wire to the frame on which the magneto is screwed down.

Another plan is shown diagrammatically in fig. 39. The end of the armature wire is joined to a block *w b*, which is fixed inside the hollow axle *h a*. The axle runs in ball bearings in the face plate *F P*. Screwed on to this is a cap *c p* supporting the contact gear though insulated from it by *i*.

c b is a contact block pressed against *w b* by a

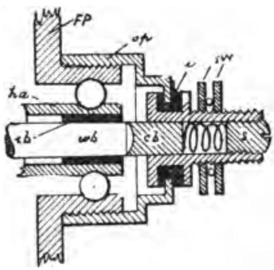


Fig. 39.—Armature contact without brushes.

spring whose pressure can be adjusted by the screw *s*. The contact surface of *w b* is convex, that of *c b* is concave, so that they rub with very little friction, as *w b* turns round with *h a*. The current passes from *w b* to *c b*, then through the containing tube to the external wire gripped between the screw washers *s w*.

43. **Low Tension Magneto.**—A low tension magneto is one whose armature is wound with about 150 or 200 turns of fairly thick wire, covered with a double layer of cotton as insulator. One end is joined to the core, the other is brought to external connection in one of the ways described.

The Castle machine shown in fig. 40 is of the low tension type, and will serve as a specimen of the class. The "live" end of the armature coil is brought out by a plan very similar to that sketched in fig. 39. There is very little connecting up. A wire is joined at one end to the magneto screw washer terminals *s w*, fig. 39,* and at the other to

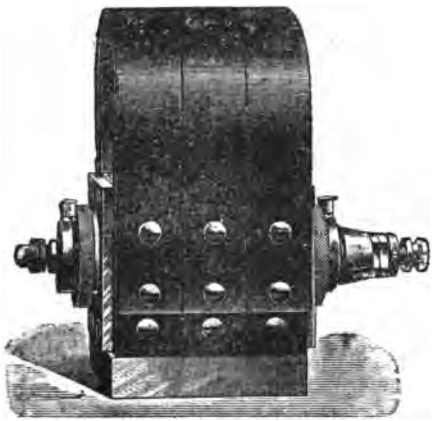


Fig. 40.—Low tension magneto.

the "live" pin *l c* of the contact points shown in fig. 42.

A low tension magneto like this is usable in two ways, with very little difference in the design. One is that shown in fig. 41, where the magneto and a battery are arranged together. Either magneto or battery can be switched into the circuit by means of the switch shown on the side of the coil, but it is impossible for both to be on at the

* These are seen on the left of fig. 40.

same time. Either can give the current for the primary of the coil. A car can be started by the battery, and the magneto substituted when the car is running.

44. **Low Tension System.**—The term low tension refers chiefly to the system of sparking in which no plug is used, fig. 42. A circuit of low resistance includes the magneto and a tappet contact inside the cylinder. A strong current flows, and when it gets to the maximum value, the tappet contact is broken, and an air gap formed. The momentum

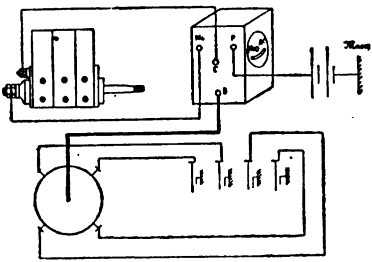


Fig. 41.—Battery and low tension magneto on same distributer.

of the current carries it across the gap as a bright hot spark.

Fig. 42 shows one form of the tappet movement. The half-speed shaft carries a cam, which for the most part is holding up the tappet rod *t r*. *b* is a guide box for *t*, and it also carries a spiral spring *s* pressing against a shoulder fixed on the tappet.

E C is the engine cylinder. Its wall supports a pivot pin *p* which carries arms a_1 and a_2 on the outside, and a third arm a_3 on the inside (shown dotted). A second pin *l c* (live contact) also goes through the cylinder wall, but this is insulated by a bush made of mica. The inside lever arm a_3 is

made to press hard against $l\ c$ by the action of an external spring s_2 which pulls down the arm a_2. The letters $l\ c$ indicate that this is the "live contact" piece, and must be carefully protected with regard to its insulation. The circuit is very simple. $M\ A\ C$ represents the magneto armature coil. The earthed end is in contact with the inside contact lever a_3 through the engine wall and the pivot p. The "live" terminal of the magneto is joined to the pin $l\ c$. As long as $l\ c$ and a_3 are

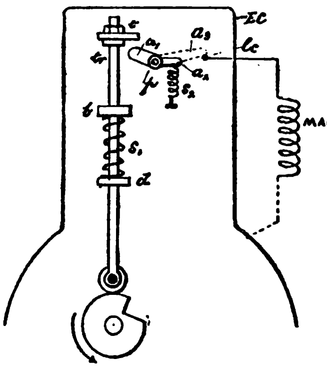


Fig. 42.—Low tension spark gear.

in contact, the current from the magneto flows easily through a circuit of low resistance. Consequently a current of many amperes is established, at any rate at the moment of maximum effect in the magneto (see par. 40).

Just at this moment the cam allows $t\ r$ to fall; the tappet t knocks down a_1, and in so doing rotates the pivot p, and drives a_3 away from $l\ c$ quite sharply. The momentum of the large current carries it across the gap thus formed, the spark

being very hot. By the setting of the magneto and the cam, this spark is made just at the time when explosion is required.

Timing is arranged in various ways. One is by mounting the armature on a sleeve so that its relation to the driving gear can be changed by rotating the sleeve on the shaft (see par. 48).

Another plan is to rotate the cams which operate the tappet rods, fig. 42, so that the tappet rod falls a little earlier for "advance," or a little later for "retard."

Where a low tension magneto runs a multi-cylinder engine, the cam must act two or four times for every revolution of the half-speed shaft.

For the somewhat rougher work of the motor-bus it is not unusual to "time" by adjusting the position of the tappet on the tappet rod. The latter has a screw thread on it, and the tappet is secured at any desired "position" by locked nuts. In this case there is no easy "time" change while running.

EISEMANN HIGH TENSION SYSTEM.

45. **The Eisemann High Tension System** is in reality a low tension magneto working a spark plug through a non-trembler coil. Yet it is very different from any other system in its general working (see figs. 43 to 48).

1. It operates the coil by suddenly *establishing* a current in its primary. In every other case the coil is worked by suddenly *stopping* the current already flowing in its primary (compare par. 17).

2. The primary coil of the non-trembler is never switched out of circuit. It is permanently joined to the magneto, but is generally short-circuited by two conductors, which also act as contact points.

3. At the moment when the magneto is putting its maximum current through these contact points,

a cam knocks them apart and the current flowing is carried through the primary coil by an enormous momentum. This very sudden rush—with its equally sudden growth of magnetic field (par. 21) —at once gives the spark in the secondary.

Fig. 43 is the simplest diagram that can be drawn; the details are shown later. *A C* is the armature coil of the magneto. *P* are two platinum contact points, which can be separated by the cam *C;* these points are joined to the ends of the armature coil.

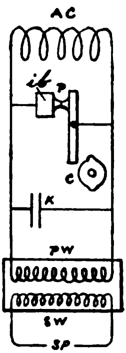


Fig. 43.—Diagram of Eisemann system.

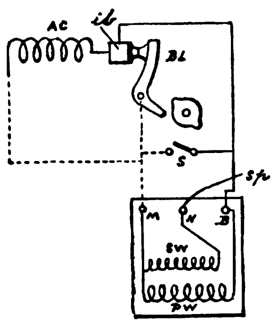


Fig. 44.—Eisemann system.

K is a condenser with its plates joined also to the leads from the armature coil. It is also obviously joined to the contact points at *P*.

P W is the primary winding of a non-trembler induction coil, also joined to the leads from *A C*. The secondary is joined to the spark plug.

The points of importance are :—

First, there are two circuits independent externally. One is that which comprises the magneto coil and the points *P*.

Another is the magneto coil and the primary *P W*. To distinguish these we shall call the first circuit (namely, that through *P*) the short circuit. The other we shall call the primary circuit. The primary circuit and the short circuit are in *parallel*, which is quite contrary to the *series* arrangement in accumulator high tension systems.

Theoretically the current from *A C* will divide between the two parallel conductors *P* and *P W*, but practically all of it will go through the contact points *P*, because the conductivity of this branch is so much greater. This is due to its short length. There is a very much greater length of wire in the branch *P W*, and the wire is much thinner. Hence we may say that as long as the points at *P* are in contact, the magneto current flows through them, and them alone.

Secondly, the cam knocks the points apart at the moment when maximum current is flowing through them. As the current possesses enormous momentum and finds the air gap at *P* an obstacle in its path, it turns into the second branch (the primary) with great suddenness. So suddenly does the current *start* in this primary circuit that the effects produced are comparable with those ordinarily obtained by the *stoppage* of a primary current.

A magnetic field starts into existence with great rapidity and sets up a high electric pressure in the secondary, sufficient to yield an excellent spark.

Thus the secondary spark is obtained when the primary current is *established*. In the accumulator high tension systems, we saw that the magnetic field of the core in the coil could not be *produced* quick enough to set up a really high tension pressure in the secondary, and that the designers relied on being able to get a secondary spark by bringing about a very rapid collapse of the field. To make

the magnetic waves collapse as quickly as possible they used a condenser across the trembler points.

We now see that in the Eisemann system the momentum of a strong current is used to *start* a primary magnetizing current in an equally short time, and to make the *outflow* of magnetic waves as violent as the *inflow* of the other systems.

The result on the secondary circuit is the same; a hot good spark is obtained. The system is a very ingenious and interesting example of the utilization of what was once regarded as a mischievous feature of a current.

A word or two may be said about the condenser *K*. It acts as if it were an electric spring. When the points at *P* open and the current rushes down to the primary, the pressure (due to electric momentum) is very great. Yet it cannot establish a current through *P W* instantaneously. The electricity naturally existing in *P W* possesses electric inertia. If it were moving, it could not be stopped at once, and in the same way, being at rest, it cannot be set in motion at once. Yet the momentum of the current from the magneto will not permit of delay; the pressure rises so high that if there were nothing to check it, the current would rush across the air gap at the platinum points. The condenser prevents that. It absorbs the momentum energy like the spring buffers in a railway terminus (par. 26) and gives it back to the primary winding in a more regular manner. The condenser relieves the system from the excessively high electric pressure which arises when the air gap is being thrust in the path of a powerful current.

Fig. 44 is intermediate between our very simple diagram of the Eisemann System and the details which follow.

One end of *A C* goes to earth or frame; so also do the pivot of the bell-crank lever *B L* and the

M terminal of the coil. These three are therefore joined together as in fig. 44. The condenser is in the coil case and joined to *M* and *B*, which connect it respectively to *B L* and the insulated block *i b*. These, of course, are the same as the contact points. For those who are not used to electric circuits it will be an interesting exercise to trace out the simiarity of the two figures 43 and 44.

46. **Details of Eisemann Magneto.**—It will be

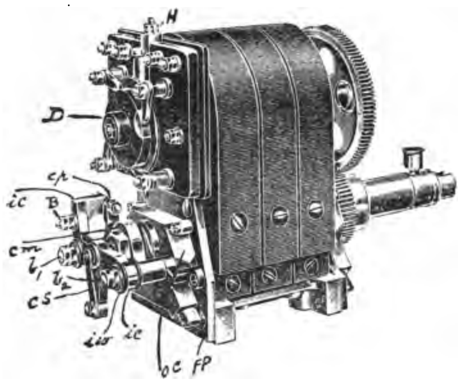


Fig. 45.—Eisemann magneto.

much easier to follow the details of this machine if the reader will take them in sections, and refer them to the simple diagrams. Fig. 43 shows that there are three parts to follow: the coil, the condenser, and the mechanical break. Fig. 44 shows that each of these branches has one end to earth, and also indicates how the terminals of the coil are lettered. Let us deal first with the mechanical break. Fig. 45 gives a general view of the machine. Figs. 46 and 47 give the necessary views of part of

the low tension gear, the lettering being the same in all.

Fix attention on the insulated casting *i c*, figs. 46 and 47. It is the part by which one end of the low tension gear is kept "alive," that is, free from earth connection.

The contact point p_1 (fig. 46) is kept in good brush contact with the end of the armature wire. The method of doing this is best seen in fig. 47. In this, *A w* is the armature wire brought into the hollow spindle *h s* and there permanently connected

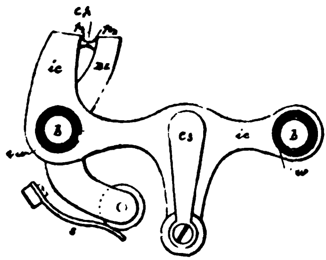


Fig. 46.—Details of magneto.

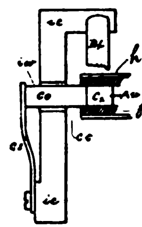


Fig. 47.—Details of magneto.

to a metal rod C_2. This rod is fixed inside *h s* by an insulating fibre brush *f b*. It is evident that C_2 rotates with the armature. Pressing against its rotating end is the carbon tip of a copper plug *C o* which passes loosely through the middle of the insulated casting *i c*. The contact spring *c s* serves two purposes. It keeps *C o* pressed against C_2, and it makes effective contact between *C o* and *i c*, because it presses against one and is screwed into the other.

It is evident now that this makes good the connection from *A w* to the contact point p_1. We have now to see how the whole is insulated.

As shown in fig. 47, the armature spindle does not project as far as the casting *i c*. The latter is carried by two bolts *b b*, fig. 46, but insulated from them by fibre brushes and insulating washers *i w*. Hence *i c* and all that is connected with it are insulated from the body of the machine except when its contact point p_1 is touching p_2, which is the condition of success (see fig. 46)—p_2 and all the other parts of the low tension gear have to be joined to the frame. The bell-crank lever *B L* rocks on the bolt b_1, and has its lower end pressed upward by a spring *s;* both these give it sufficient "earth." The "earthed" end of the armature wire is one with the spindle. As this might not make good contact with its bearing (films of oil possibly interfering) a special contact is made between it and the bolt b_2, fig. 45, by a thin, flat spring. This is secured to b_2 and has its inner end forked. The prongs are faced with studs, which press against the back of the rotating cam.

The thin edge of this spring is seen behind the cam in fig. 45.

47. **High Tension Gear.**—In the case of single-cylinder engines, all that is necessary is to connect the high tension terminal of the induction coil to the spark plug, as suggested in fig. 44. Where a multi-cylinder engine is used, the Eisemann magneto carries the high tension distribution gear. A comparison of fig. 48 with the upper part of fig. 45 will make the action clear. An ebonite disc, *D* (fig. 45), has a smaller boss projecting from it *on its hidden face*, and on the boss is fixed a brass ring. A metallic segment runs out from the ring and spreads into a broader contact face at the circumference. The contact face is on the front of the distributer, and can be seen in fig. 45, although the segment connecting it with the brass ring is hidden. Above and behind the distributer disc is the

terminal *H* for the high tension wire from the coil. This is continued below by a tube in which is a spring pressing a carbon block against the ring just referred to. The whole arrangement is laid bare in fig. 48. A rubbing contact is thus preserved between the terminal *H* and the contact face piece on the circumference of *D*. The contact face touches successively the four pawls, 1, 2, 3, 4, which are joined to the four spark plugs. Fig. 48 shows

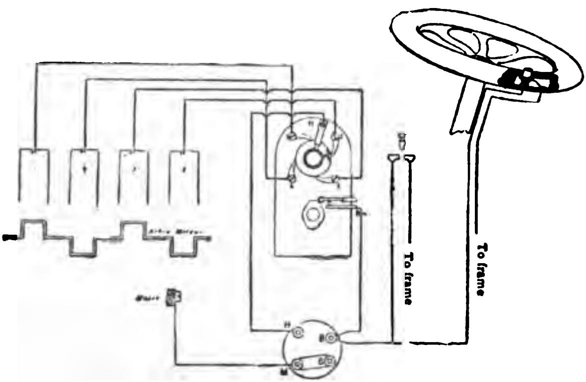


Fig. 48.—Eisemann distribution gear.

one way of joining up successive points on the distributer to the cylinder. The order for pawls being 1, 2, 3, 4, that for cylinders is 1, 4, 3, 2.

The distributer is driven from the armature spindle by two spur wheels seen at the back of the magneto in fig. 45. The spindle of the larger wheel runs under the arch of the magnets. This wheel has twice as many teeth as the smaller one, and runs at half its speed.

There remains the question of wiring; and this

is simple. There are six terminals on the magneto. Two of them are lettered *B* and *H* in figs. 45 and 48. The other four are connected to the pawls which touch the distributer. *B* is the only one connected with the low tension side.

Joining up low tension. From the terminal *B* fixed on the insulated casting *i c* take a wire to the corresponding *B* terminal on the coil. As the contact point p_1 is directly joined externally to *B* and internally to the end of the armature coil, the wire thus run joins the armature coil to one end of the primary circuit.

The frame (or *masse*) terminal *M* of the coil is now joined carefully to the framework of the car, and so joins the second end of the armature coil to the second end of the primary.

High tension. Run a highly-insulated wire from the "live" secondary terminal *H* of the coil to the corresponding terminal *H* at the top of the distributer (see fig. 48).

Then take highly insulated conductors from each of the pawl terminals to a spark plug.

The coil used is a non-trembler coil, and is provided with a safety spark gap inside. As seen in plan in fig. 48, there are four terminals marked *H*, *B*, *B*, and *M*. The two *B* are really one, as they are permanently joined together. The second one can be joined to the terminal *M*, which has to be joined to earth (or frame). A switch arm is shown connecting the two. This arm, of course, short circuits the primary winding and cuts it off from the current.

It is noteworthy that in the Eisemann system the switch has to be connected up in parallel with the apparatus it has to cut out. This is contrary to the usual arrangement of a switch, which is commonly in series with some apparatus and serves the purpose of completing or opening the circuit.

Compare the diagram of fig. 44 with the switch in fig. 9.

Timing is accomplished by rocking the armature on the shaft. The armature is mounted, not on the shaft but on a sleeve, fig. 49, in which there is a longitudinal keyway or slot. The shaft also is hollow and has a spiral groove in its wall. Inside the shaft is a rod with a projecting pin which passes through the slots in both shaft and sleeve. The pin therefore serves to gear the armature shaft and the sleeve together.

Suppose now that the pin is in the middle of

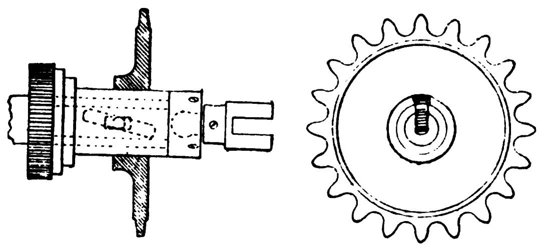


Fig. 49.—Timing gear of Eisemann magneto.

each of the two slots: the armature core (mounted on the sleeve) and the spindle will have a certain definite relative position. Further, suppose that the spindle is prevented from rotating, and that the rod inside is pushed further inwards, then the pin must travel spirally (as it moves in the spiral groove of the spindle). But in so doing it will carry the armature round with it, for the slot in the sleeve is straight, and yet it will have to follow the pin, which is really going round as well as forward.

Evidently, by pulling the rod and pin out, the

armature can be made to rotate on the spindle in the reverse way.

By thus advancing or retarding the position of the armature core on the spindle, the moment of maximum effect and of sparking can be advanced and retarded. The spiral and straight slots are seen dotted in fig. 49.

The Simms-Bosch High Tension System.

48. **Preliminary.**—This system is very different from the others. First, the armature is fixed. The

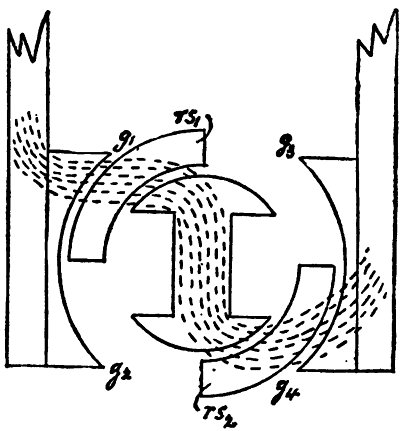


Fig. 50.—Magnetic flow in Simms-Bosch magneto.

magnetic disturbance which produces the electric pressure in the armature coils is brought about by the rotation of soft iron segments between the pole pieces and the armature core. Secondly, the armature core is wound with two coils connected in an unusual way.

These points will be taken in order.

49. **Magnetic Conditions.**—Figs. 50 to 50*c* show the magnetic arrangements and explain how the magnetic disturbance is produced. It will be noticed that in each of them the iron core is in the same position, but that two iron shields marked $r\ s_1$ $r\ s_2$ rotate round it.

Remembering that magnetic lines tend to pass through iron rather than through air, it is easy to see that the movement of these shields will cause a great movement of the lines.

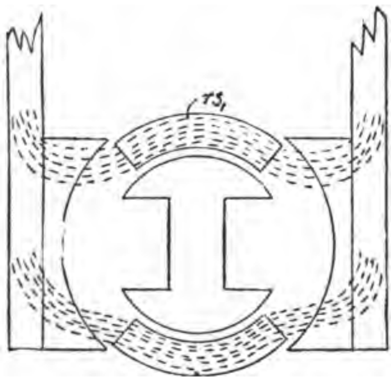


Fig. 50*a*.

In fig. 50 the iron shields are unsymmetrically placed, $r\ s_1$ on the top left, $r\ s_2$ on the bottom right, and they cause a marked disymmetry in the air gaps. The gaps g_1 and g_4 are narrow; g_2 and g_3 are wide. Consequently the lines pass chiefly through the narrow gaps, even though they have to stretch very much. *Notice that this means that they pass through the armature coil and coils.*

In fig. 50*a* the lines are cut out of the coil because the shields themselves extend almost from

pole to pole, and offer a very easy magnetic path. This means that few or no lines go through the core and coils.

In fig. 50*b* the lines pass through the coil again because of unequal air gaps. But g_2 and g_3 are now the narrower ones; g_1 and g_4 are the wide ones. The lines therefore pass through the armature core, and it coils in a reverse direction from

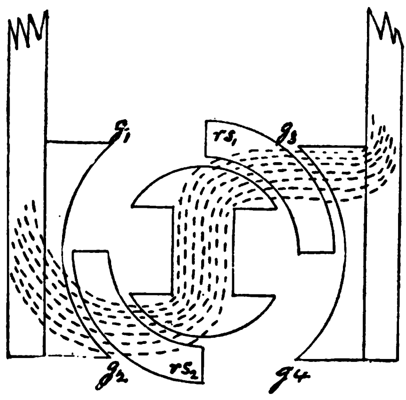


Fig. 50*b*.

that shown in fig. 50. In fig. 50 they go through from above, in fig. 50*b* from below.

Fig. 50*c* the two shields are inside the pole pieces, and they make all four air gaps equally narrow. Finding their way through iron more easily, the lines pass through as shown here. Practically none of them go through the centre core and its coils.

If the shields continue rotating after leaving fig. 50*c*, they will come to fig. 50 again with the

difference that $r\,s_1$ and $r\,s_2$ will have changed places. This will, however, make no magnetic difference, for one shield is magnetically like the other. Hence we have this result, that at the end of half a revolution the shields are opposite to where they were at the beginning, but that magnetically the machine is exactly in the same position.

Now when dealing with an ordinary magneto core (see figs. 33, 34, 35) we saw that in one half revolu-

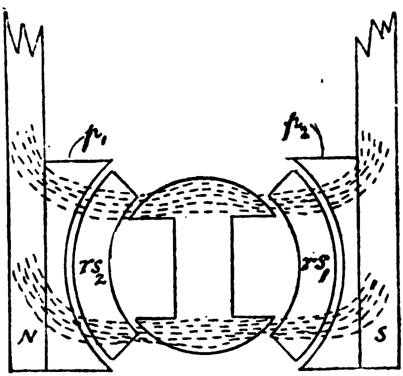


Fig. 50*c*.

tion there were only two significant positions which we must emphasize as much as possible.

In the first we have :—

Maximum number of magnetic lines threaded through coil	associated with	minimum value of electric pressure in the coil.

In the second position we have :—

Minimum number of magnetic lines threaded through coil	associated with	maximum value of electric pressure in the coil.

We also saw these effects reproduced in the second half of the rotation.

If these points be carefully noticed, the reader will easily tell where the corresponding points are to be found in the Simms-Bosch machine. There will be a *maximum electric pressure* whenever the magnetic lines through the coil are fewest; that is, in the positions like 50*a* and 50*c*. There will be a minimum or zero electric pressure whenever the magnetic lines through the coil are most numerous, as in figs. 50 and 50*b*.

Keeping now to the points of maximum electric pressure (figs. 50*a* and 50*c*), notice that these points are only 90° apart; that is to say, the shields only rotate a quarter of a revolution in passing from one electric maximum (due to fig. 50*a*) to the next maximum (due to fig. 50*c*).

Now it will be evident that these effects will be produced every time the shields pass from one of these positions to the other.

In other words, the electric pressure will have a maximum value every quarter revolution of the shields, or four times in every revolution they make.

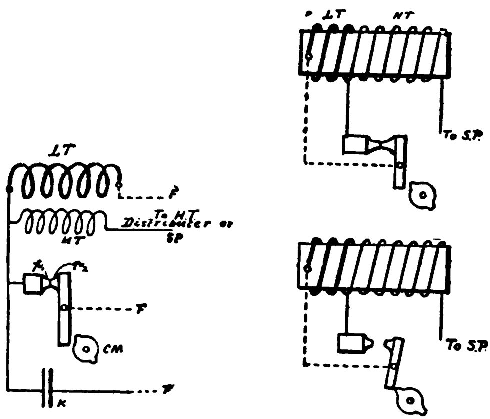
This is twice as many maxima per revolution as is obtained with the ordinary magnetos, and constitutes a difference which must be taken into account when arranging the timing gear.

We also see that theoretically these maxima will appear when one shield is at the top and the other at the bottom (which is twice per revolution) as in fig. 50*a*; and also when one is at the right and the other at the left (also twice per revolution) as in fig. 50*c*.

For reasons given in pars. 12 and 61 the maximum voltage will not appear just at these theoretical positions, but at points somewhat later. They will be slightly thrown forward in the direction

of rotation. In other words, they come a little later in the rotation, at a position found out by the maker by repeated trials.

50. **Armature winding.**—In the Simms-Bosch armature are two coils and a method of connecting which is quite unusual. To make this quite clear two diagrams are given, one to reduce the system to its utmost diagrammatic simplicity, the other to show how the coils stand related to the armature core.



Figs. 51 and 52.—Diagram of winding Simms-Bosch magneto.

Figs. 51 and 52 show the results. The whole of the apparatus included here is embodied in the magneto. *L T* is the low tension wiring on the armature core (wire rather thick, comparatively few turns). *H T* is the high tension wiring on the *same core* (thin wire, many turns) p_1 p_2 are contact points connected to the low tension, p_2 being carried by a lever which is knocked away by the cam *c m*, p_1 is insulated from the frame. *K* is the condenser, joined to the contacts

$p_1 p_2$. As usual, one end of the *L T* coil is joined to the frame; so also are the lever and one side of the condenser. The frame therefore is used to join these together.

The other end of *K*, of *L T*, and one end of *H T*, are "live" ends. They are joined together and also to the insulated contact block to which p_1 is fixed. The peculiarity in the function of the two windings lies in this, that the *H T* wire is not joined to the "earthed" end of *L T* but to its live end. This is contrary to the rules followed in induction coils and in other devices where two windings are employed. The following points must be remembered and interpreted in connection with the diagram in fig. 52, in which the direction of winding the coils round the iron core is shown. It is assumed that the shields start from the zero voltage positions, figs. 50 or 50*b*, and that they turn as far as figs. 50*a* or 50*c*.

1. During most of this movement, voltage is being induced in both the *L T* and *H T* windings by virtue of the change in magnetic lines through both. This voltage will begin on zero and slowly increase for a while, then rapidly rise to a maximum, the critical position.

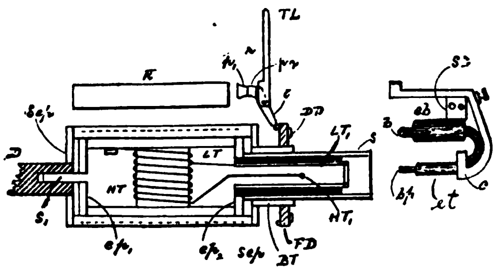
But though the pressure in the high tension coil is much higher than that in the low tension, current flows only in the latter. The *L T* coil is *short-circuited through the contact points and frame,* and has therefore a complete conducting circuit of low resistance. Contrary to this, the *H T* coil circuit is open, because of the air gap at the spark plug (fig. 52). Hence the difference in current.

2. As the maximum position is approached, the voltage in the *H T* approaches the sparking value, and there is a strong current flowing in the *L T* coil, and therefore through the contacts $p_1 p_2$.

At this moment the cam opens the points in the

low tension circuit (fig. 52) and the consequences are interesting. The $L\ T$ and $H\ T$ coils become one; the voltage acting in the $H\ T$ is suddenly reinforced by the great momentum pressure of the $L\ T$ current. The joint effect is to raise the voltage to a very high value and a fine explosion spark is produced at the plug.

51. **Details.**—Fig. 53 shows how the parts are actually arranged, though the diagram is drawn for explanation and is distorted. The live ends of the $L\ T$ and $H\ T$ coils are shown. $L\ T$ goes to a metallic tube $L\ T_1$ inside the spindle S. $H\ T$ is



Figs. 53 and 53*a*.—Details of Simms-Bosch.

joined to a rod $H\ T_1$ which lies inside the $L\ T_1$ tube. The rod $H\ T_1$ is enclosed in an ebonite tube (not shown) and is thus insulated from $L\ T_1$. A similar insulating tube lies between $L\ T_1$ and the spindle.

None of these revolve. They are secured in a tube S which springs from the *armature* end plates $e\ p_2$. S is supported by a casting which also fixes it. On the casting is a boss, through which passes a screw bearing hard on a flat on the side of the spindle. As the casting is fixed to the front of the magneto, and S, with the armature, is kept to it

by the screw, none of them can rotate in any degree.

The rotating part consists of end plates *s e p* (sleeve-end-plates) which carry the sleeves. These are all driven by the shaft *D* fixed into the left-hand sleeve-end-plate. The other sleeve-end-plate carries a short brass tube *B T* which turns on the hollow spindle *S*. Support for the left-hand end of the armature is found by fixing a short spindle S_1, to receive which a bearing recess has been bored in *s e p* and *D*.

The distribution gear can be understood by a

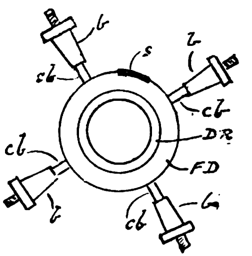


Fig. 53*b*.

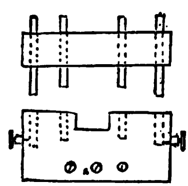


Fig. 54.

comparison of figs. 53, 53*a* and 53*b*, which are not drawn on the same scale. The connections from the inside stationary ends $L\ T_1$ and $H\ T_1$ are made by the device shown in fig. 53*a*; the end *b p* is thrust into the tube $L\ T_1$ until the brass plug *b p* touches the end of the rod connected to the high tension gear. Here it is fixed by nuts in such a way that $L\ T_1$ fits into the lower end of the casting *C*, whose upper end comes near to the contact points p_1 and p_2. This upper end is then connected by springs with the "live" contact p_1 and also with one end of the condenser *K*. Thus the casting *C*

joins the wire $L\ T$ to p_1 and K, and thus completes the low tension gear.

At the same time, the ⊃ shaped conductor (insulated in the ebonite tube $e\ t$ and ebonite bush $e\ b$) joins the high tension end $H\ T_1$ to a distributer ring $D\ R$ fixed on the face of a fibre disc $F\ D$,

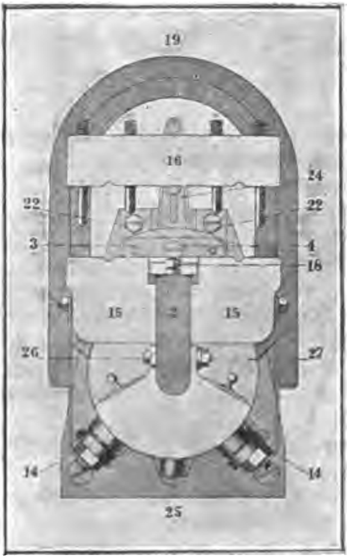


Fig. 54*a*.—Front view of one form of Simms-Bosch magneto.

fig. 53 (a front view of this disc $F\ D$ and distributer ring $D\ R$ is given in fig. 53*b*), the end $b\ p$ is a brass plug which makes contact with $H\ T_1$; the other end b is a brush pressing on the ring $D\ R$.

The fibre disc $F\ D$ and therefore the ring $D\ R$ are fixed to the brass tube $B\ T$ which revolves

with the sleeves and sleeve-end-plates, *s e p*. The ring *D R* is joined to the brass segment *s*, which is fixed on the edge of the disc, fig. 53*b*. As this is brought successively into contact with the four distributer brush contacts pressing radially on the edge, it is evident that the high tension winding is brought into contact with these high tension brushes in a very simple and efficient way. Each brush contact is joined to one of four sockets in a distributer plug board fixed on the front of the magneto. This is shown separately in fig. 54, and seen in the front view fig. 54*a*.

The upper part of the board has four plugs, which fit into the sockets on the lower half. The plugs have screw threads turned on their upper ends, to which highly insulated wires are secured by nuts, their other ends going to the four spark plugs in the cylinders. It will be noticed that the sockets and plugs, fig. 54, are unevenly spaced, so that it is impossible to reverse the upper half. Hence the high tension gear can be disconnected by simply lifting the upper half of the board, and, in restoring it, there is no chance of altering the connections.

The connecting piece of fig. 53*a* serves for both high and low tension, as we have seen. It also carries a safety spark gap, *S G*, which protects the insulation against any very excessive pressure. It consists of a spark gap a little more than one-eighth of an inch wide, one wire being connected to the low tension side (the casting *C*, fig. 53*a*); the other to the high tension conductor running from *b p* to *b*. This safety spark gap is therefore in parallel with the gap at the spark plug in the cylinder. Sparks will occur in the cylinder as long as things are right, because it offers an easier path than that in the safety gap. But if the working spark gap goes wrong, the discharge will occur at

this safety valve. If it were not there, the pressure would find some path through the insulation, and sooner or later wreck it.

It only remains to explain how the contact points in the low tension circuit are operated. The fibre disc *F D*, fig. 53, carries on its *inner* face some cam-like projections, two or four in number. As *F D* revolves, these strike and knock away to the left the lower end of a lever *l*. Its upper end and the contact point p_2 is thus jerked away from p_1, giving a sudden break in the lower tension circuit, and throwing its current with a violent momentum into the high tension circuit as explained.

Timing is managed through the timing lever *T L*, fig. 53. It will be observed that the contact lever *l* is pivoted in the forked end of *T L*, an edge view of the last being shown in fig. 53. When *T L* moves, the movement is not in the plane of the paper, but at right angles to it. If the upper end be moved towards the observer, its lower end, and also the lower end of *l*, are moved away from him. Consequently a little extra time must elapse before the cam projections on *F D* knock *l* away from its live contact. With reverse motion of *T L*, the points are separated a little earlier.

When fixing the machine, it is usual to set the lever to the retard position, and the piston so that it is in the position of maximum effect. Then at higher speeds a reasonable timing range is obtained by "advancing" the lever.

52. **Other Magnetos.**—There are many other magnetos, well-designed and successfully used; but they do not call for special remark except in some cases. Mr. Lanchester brought out a magneto in which the magnet had a special shape. It consisted of two bar magnets with poles in the middle. The fitting allowed plenty of iron to join the ends of the magnets together. An armature revolved

between two middle or "consequent" poles. In earlier forms of a system known as the Bassée-Michel, the magnet had a circular shape, two poles appearing at the sides; pole pieces of the usual type led the lines to the armature.

At the present time a machine called the Gianoli is earning some favour. Its chief peculiarities are the method of separating the contact points in the interrupter, and the method of timing. A primary and secondary coil are wound on the armature, and, as usual, there must be a sudden break in the primary when its current rises to a certain maximum. This is not done by a mechanical cam, but by the magnetic action itself. The armature core

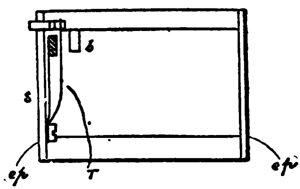


Fig. 55.—Gianoli break.

has two bosses projecting slightly inwards from the "heads" of the shuttle core. One of these, marked *b*, is shown in the skeleton diagram, fig. 55. These bosses become strongly magnetized at the time of maximum effect, and they then attract an iron plate held by two springs *S*. At the moment when the magnetism of *b* is strong enough, *S* is drawn and strikes the trembler *T*, separating the two contacts, one of which is fixed at the end of *T*. The spring and trembler *T* are fixed to the inside of one end plate *e p*. This interrupter will evidently be automatic, and act always when the magnetic effect of the bosses reaches a given value.

The second peculiarity is the timing arrange-

ment. Some timing action comes out of the interrupter. For at high speeds the armature pressure will rise quicker and magnetic effects occur sooner. But reliance is not placed on this only. The pole pieces have a kind of facing or sheath, which ordinarily looks like a simple curved addition to their thickness. But these sheaths can be rotated by a timing arrangement, and brought more or less forward in the direction of rotation, or the reverse.

By this means the magnetic field can be pushed forward or backward, and it follows that the sparking moment can therefore be advanced or retarded.

Space does not permit of further details being given.

APPENDIX

53. **Chemistry of a Dry Cell.**—Some explanation of the chemical action has already been given. Further details are best given by what are called chemical symbols. Thus the following symbols express the changes.

The original materials are:—

$$Zn + \left\{ \begin{matrix} Cl\,N\,H_4 \\ Cl\,N\,H_4 \end{matrix} \right\} + \left\{ \begin{matrix} Mn\,O_2 \\ Mn\,O_2 \end{matrix} \right\} + C$$

Zn represents one atom of zinc; $Cl\,N\,H_4$ one molecule of sal ammoniac*; $M\,n\,O_2$ one molecule of manganese dioxide; *C* one atom of carbon.

When the cell is put to work, its chemical state is altered and the change is represented by:—

$$Zn\,Cl_2 + \left\{ \begin{matrix} N\,H_3 \\ N\,H_3 \end{matrix} \right\} + Mn_2\,O_3 + H_2\,O + C.$$

Zinc chloride + ammonia + manganese oxide + water + carbon. From these two it is seen that the zinc has united with the two atoms of chlorine in the sal ammoniac, two atoms of hydrogen have united with one atom of oxygen from the dioxide to form water. If there were no manganese dioxide in the cell, these hydrogen atoms would collect on the carbon and polarize the cell.

The zinc chloride dissolves in the liquid and allows fresh zinc to be acted on as the current continues. The cell is exhausted when the manganese dioxide can no longer provide oxygen to unite with the hydrogen.

* *Cl* is the symbol of an element called chlorine; *H* and *N* indicate atoms of hydrogen and nitrogen respectively. In one molecule of sal ammoniac there are one atom chlorine, one atom nitrogen, and four atoms hydrogen.

54. **Chemistry of an Accumulator**—This can be described in a few words. Initially we have:—

(1) Spongy lead on the negative plate. This is gradually changed to sulphate of lead during the discharge.

(2) Peroxide of lead (as depolarizer) on the positive plate. This is also changed to sulphate of lead.

(3) A solution of sulphuric acid liquid. This gradually gets weaker, because the acid is being absorbed by *both plates* owing to the formation of sulphate of lead on them as mentioned in (1) and (2).

These changes can be represented by symbols as before. Writing Pb for an atom of lead, PbO_2 for an atom of peroxide of lead; H_2SO_4 for an atom of sulphuric acid; and $PbSO_4$ for an atom of sulphate of lead, we have the following.

Initial state:—

$$\begin{array}{r} Pb \\ \textit{Lead on} \\ -\textit{plate} \end{array} \left\{ \begin{array}{c} 2H_2SO_4 \\ \textit{Sulphuric} \\ \textit{acid in} \\ \textit{liquid.} \end{array} \right\} \begin{array}{l} PbO_2 \\ \textit{peroxide of lead} \\ \textit{on} + \textit{plate.} \end{array}$$

After discharge:—

$$\left. \begin{array}{r} PbSO_4 \\ \textit{Sulphate of} \\ \textit{lead on} \\ -\textit{plate} \end{array} \right\} \left. \begin{array}{c} 2H_2O \\ \textit{water} \\ \textit{formed in} \\ \textit{liquid} \end{array} \right\} \begin{array}{l} PbSO_4 \\ \textit{Sulphate of} \\ \textit{lead on} \\ + \textit{plate.} \end{array}$$

It will be understood that this only refers to the part of the materials which happens to be acted on. The cell is discharged when about half the spongy lead on one plate and the peroxide of lead on the other has been changed to sulphate as described. The other half is not available for work. The reason is not difficult to find. Sulphate of lead is a fine white powder very much like powered chalk. It is formed in the pores of the active material during discharge, and clogs up the pores more and more fully as the action proceeds. This has two results. It delays any more acid getting in, and it surrounds the remaining active material with a protecting wall. Hence it is not possible to get all the active material to take part in the action. Those cells which have the most

porous active material will be able to use a larger proportion of them, and so far have an advantage. But it must be remembered that excessive porosity *may* mean small mechanical strength, and the best cell is that which has the best combination of these different properties.

55. **Exhaustion of Cells.**—This can be ascertained in several ways. First, the plates change colour. The positives lose the rich dark brown colour of peroxide and become more or less of a brick colour. The negatives lose their bluish tint and become greyish or greyish blue. Secondly, the acid gets weaker. If the chemical symbols be examined (or even the explanatory words below them) it will be seen that sulphuric acid disappears and water is formed. Hence the liquid becomes less dense as the charging proceeds. It is often possible to tell the state of the cell by taking the density of the liquid, but this is rarely done in the case of ignition cells.

Thirdly, the electric pressure falls. It is no longer so high as 2 volts. If as low as 1·8 volts, the cell is quite discharged. If between these values, its state is intermediate. The fall in pressure arises from the weaker acid.

56. **True Meaning of Recharging.**—The methods of recharging an accumulator are given in pars. 12, 61, but there is so much misconception as to the meaning of recharging that a few words about it are desirable. Many motor men imagine that a cell is "recharged" by having a store of electricity put into it. This is not the case, no electricity is put *in*. The recharging current passes *through*, just as much going out as goes in. What the recharging current does is to reverse the chemical action of "discharge." It has already been said that a cell is "exhausted" when the substances employed have undergone a certain amount of action. The original things are then more or less destroyed: their place has been taken by the new compounds formed. If the cell is an ordinary one, it could be "recharged" by taking these "spent" materials out and putting in a fresh lot of the original. A dry cell could be recharged by putting in a fresh supply of the pastes, though it would not be profitable to do this. Notice, however, that this would bring the cell back to its initial chemical state.

Now in an accumulator this process of bringing the

chemicals back to the original state can be done by sending a current through the cell in a reverse sense. By means of a dynamo or a battery a current is made to pass through the accumulator, *entering it by the positive terminal and leaving it by the negative.* As it passes through, this current decomposes some of the liquid; it brings the sulphate of lead on the positive plate back to peroxide of lead. At the same time the sulphate of lead on the negative plate is changed to spongy lead. In both plates the sulphuric acid is removed from the sulphates and restored to the liquid.

Three consequences follow. The active materials are brought back to their original undischarged state. The peroxide plate becomes a rich dark brown colour. The spongy lead plate assumes a pure bluish colour. The liquid gets back to its original density.

Electrically the electric pressure is restored, being determined by the same chemical affinities as at first.

Special attention must be paid to the words printed in italics, from which it will be seen that the charging current goes through the cell in a reverse sense to that which obtained during discharge.

57. **Arrangement of Cells. Ohm's Law.**—It is very rarely that a cell of any type is used alone, simply because its pressure is not high enough to give the requisite current. The value of the current obtained in any given circuit depends on two things: first, the pressure of the battery: secondly, the conducting power of the circuit. A circuit of good conducting power—say one made up of fairly stout copper wires of moderate length—will permit a strong current to flow even when the electric pressure is low. Such a circuit is said to have good conductivity; or, conversely, it is said to offer a small resistance. Experience has shown that it is more convenient to speak of resistance rather than conductivity.

A standard of resistance has been chosen to suit the standards of electric pressure and of current, because the three things, pressure, current, and resistance, are related together in a very peculiar way. A celebrated German electrician, named Ohm, was the first to show how to control the value of the current exactly. He proved that the current could be *increased* by *increasing* the electric pressure and also by *decreasing* the resistance.

It therefore became necessary to choose a standard of resistance, and the unit is roughly equal to forty-one yards of No. 20 copper wire. As Ohm was the first to put this matter in its true light the name of the unit of resistance is called by his name. A conductor whose resistance is 1 ohm will permit a current of 1 ampere to flow when the pressure is 1 volt. If such a conductor be joined to a dry cell (whose electromotive force is 1·5 volts) the current will equal 1·5 amperes.

The same conductor (1 ohm) joined to a single accumulator will allow a current of 2 amperes to flow, because the pressure is now 2 volts.

As a matter of fact the units of voltage, current and resistance have been so chosen that when two of them are known, the third can be easily calculated. The following is one form of stating Ohm's law:—

$$\text{Value of current in amperes} = \frac{\text{Value of pressure in volts}}{\text{Value of resistance in ohms.}}$$

Another form of the same law is the following:—

$$\text{Pressure required in a given circuit} = \text{Working value of current.} \times \text{resistance of circuit.}$$

This form is very useful. When a circuit has been arranged, it will consist of a certain length of wire of a given size or sizes, and will therefore have a certain resistance. Let us suppose this is equal to 1·2 ohms, and that the current required for working the apparatus (say coil) is about 3 amperes. Then Ohm's law tells us that the requisite pressure (voltage) is equal to

$$\text{Value of current} \times \text{resistance of circuit;}$$
$$\text{or} \qquad 3 \text{ (amperes)} \times 1{\cdot}2 \text{ (ohms)}$$
$$\text{which} = 3{\cdot}6$$

That is to say 3·6 volts is the lowest voltage which will give the working current in this particular circuit.

Experience shows that to get an efficient current through an induction coil requires a pressure of about 4 volts, which is higher than the voltage of any single cell. But two accumulators can be joined in series, and

then their pressures are added. They will then give 4 volts. The method is to join the negative pole of one cell to the positive pole of the other as shown in fig. 3.

When dry cells are used, it is usual to put four cells in series, as suggested in fig. 3. The four cells then exert a pressure of $1{\cdot}5 \times 4 = 6$ volts. The reason for using higher pressure with dry cells arises from the simple fact that they have an internal resistance much higher than that of accumulators, and are also much more liable to polarize.

The total resistance of a circuit includes the resistance of the connecting wires, plus that of the coil, plus that of the battery. The resistance of wires and of coil will be the same whether accumulators or dry cells are employed. But as the dry cells add more resistance than the other cells, they make the total resistance higher, and it becomes necessary to have a higher pressure if the same current is to flow through the coil. Hence the use of four cells instead of three, which at first would seem to be enough.

58. **Local Action.**—Theoretically, a good cell ought to suffer no loss when the circuit is incomplete. The chemicals ought not to act on each other, however much they may be straining to do so. The only result of the strain should be to produce an electric pressure.

But in practice there is some action on the zinc or lead, &c., even when the cell is at rest. These materials, which may be called the fuel of the cells, are slowly acted on, and the dissolved part ceases to be available for the purpose of maintaining a current. This slow, internal eating away, is called "local action." It generally arises from impurity in the material: sometimes from unavoidable contact of different solid substances. Local action also arises from careless workmanship, causing differences of concentration or hardness, &c., at different parts of the plates.

These two causes—impurity and imperfect workmanship—are more or less preventible, and it is for this reason among others that cells made by good firms work better than others.

The general result of local action is to diminish the capacity of a cell. It eats away the zinc in an undesirable way. It leads to internal electric currents, that is

currents which flow locally inside the cell and are therefore not available for outside use.

A useful example is that of an accumulator whose capacity is, say, 30 ampere hours. Suppose that after being charged the cell is not used for some weeks. During that time the acid is *slowly* acting on the spongy lead and also on the peroxide of the other plate. This will be going on night and day, so that at the end of the six weeks one quarter of the available material may have been used. If the cell be put into work, its capacity may appear to be no more than 20 ampere hours instead of the 30 specified. The remedy for this is to charge accumulators afresh after a long rest, even if they have not been in action.

In the case of dry cells, which are put up a long time before they begin to work, local action may impair their capacity. It is for this reason that some of them (like the moto-capsule cell, par. 10) are so made that the liquid is kept apart from the other materials till the cell is to begin its working life.

59. **Capacity of Cells.**—A most important point about a battery is its capacity, that is its current maintaining ability. Sometimes this capacity is stated in miles. For example, the capacity of "our cells" is advertised as 800 miles, meaning that they will keep the ignition spark going through journeys mounting up to 800 miles. But this way of reckoning is often misleading. It assumes that the current will have the same value on all the cars to which the cells are fixed. Yet some may have coils that take a greater current than others. Suppose, for example, that 800 miles are run on a car whose coil takes a current of 1·5 amperes, and that a similar battery is afterwards fitted to a coil taking 3 amperes. Then the cells will only run 400 miles, although the capacity is the same. In the shorter run the cells have given out twice the *current* for half the time. They have given out the *same quantity of electricity.*

The proper way to state capacity is in ampere hours. Accumulators are made to have capacities of 30, 40, 60, or more ampere hours. The phrase 60 ampere hours, means, that if the current be measured in amperes, and the time of discharging in hours, then exhaustion will come when the product of amperes and hours comes to 60.

For example, exhaustion will occur with:—

1 ampere running for 60 hours; or
2 amperes running for 30 hours; or
1·5 amperes running for 40 hours; or
3 amperes running for 20 hours.

A little thought will make the phrase ampere hour more or less intelligible. Every current means that zinc (in a dry cell) or lead (in an accumulator) is being chemically consumed or rendered useless. It is well known at what rate any given current will consume zinc or lead in this way. Let us keep to lead as an example.

One ampere flowing for an hour means that 60 grains of lead will be sulphated in each cell. If the same current flow for two hours, 120 grains of lead become useless.

Or if the current be doubled, then 120 grains of lead will be consumed in one hour.

Hence we may say that 1 ampere hour expresses the quantity of electricity circulated by the consumption of 60 grains of lead in the accumulator.

If now a cell has 2 ounces (=900 grains) of lead available for work, it can evidently yield 15 ampere hours.

If a cell has a capacity of 60 ampere hours, it must have available lead equal to 3,600 grains, or about 8 ounces.

In corresponding fashion, the capacity of a dry cell depends on the weight of zinc which can be utilized for circulating electricity. The weight of zinc required may be reckoned from this: each ounce of zinc will yield about 20 ampere hours.

60. **Comparison of Dry Cells and Accumulators.**—There are some points which are immediately obvious. A dry cell battery costs less money than an accumulator. It can therefore be installed and replaced more easily. It runs on from the date of starting till it is exhausted, and must then be renewed: a feature which makes its treatment a bit more simple than the "recharging" which an accumulator needs. Again, a dry cell does not spill liquid when upset.

These are advantages. On the other han, an accumulator battery has a much lower internal resistance and is less subject to polarization. Consequently it can give stronger currents than a dry cell, and can also

maintain them. When discharged, the cost of recharging is very much less than the initial cost, and it practically brings the cells back to their first condition.

As a general rule, accumulators are to be preferred. In special circumstances, dry cells may be better; for example, if recharging is difficult.

These comparisons, however, are not very reasonable unless they are taken in conjunction with other points. For example, on old cars it is sometimes found that contact breakers which involve the use of platinum points last longer with four dry cells than with two accumulators. The reason is simple. The platinum points have to be large enough to stand the heating effect of the current and the spark at "break," and they must be designed to suit the currents passing through them. It happens that they have been designed for such currents as a dry cell battery will yield. With such currents they are not warmed to any injurious degree. But two accumulators put on the same coil and circuit breaker may send larger currents through, and lead to a more rapid deterioration at the points. Thus a possible virtue of the accumulator turns into a defect, because it is linked with a device of unsuitable size. There is an easy remedy, however. A foot or two of No. 18 German silver wire introduced into the circuit of the accumulator prevents the current becoming so strong, and thus economizes the working value of the cells.

61. **Methods of Recharging Accumulators.**—This may be done by battery, by dynamo, or from electric lighting mains. In most towns, it is now undertaken by any garage, or motor engineers. In out-of-the-way places it is done by a battery. The charging current must be sent through the accumulators in a reverse sense to that in which their voltage acts. Consequently the voltage of the charging battery or dynamo must be higher than that of the accumulators, or it will not be able to urge a current through. Generally speaking, the charging battery must give about 5 to 6 volts when a 4-volt accumulator is to be charged.

It must also be able to maintain a steady current for some hours. Hence many cells are unsuitable. One of the most commonly used is a cell in which carbon and zinc are used as the positive and negative elements. The carbon plates stand in an outer earthenware jar,

and between them is placed a porous earthenware pot containing a thick zinc rod or plate amalgamated with mercury.

The liquid in the outer jar is a mixture of dilute chromic and sulphuric acids, made by mixing—

1 part by weight of strong sulphuric acid.
4 parts „ „ „ chromic acid.
16 „ „ „ „ water.

The sulphuric acid is added slowly and cautiously with stirring, to the water and then the chromic acid. The liquid in the inner porous pot is made by adding 1 part of sulphuric acid to 8 of water. One of the best

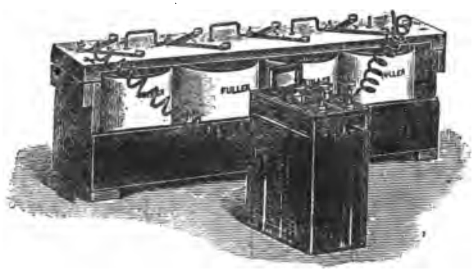


Fig. 56.—Recharging by battery.

known of this type of cell is the "Fuller." In fig 56, four of these are shown charging an accumulator. The four cells are joined in series (positive to negative). The final positive (carbon) is joined to the positive of the accumulators; the negative terminals are also then joined together. It is well to know the value of the charging current, and to get this an ammeter may be placed in circuit. The current may then be regulated by putting a little resistance into the circuit. A yard or so of German silver wire about $\frac{1}{20}$ of a inch in diameter will serve, and it can be shortened as the occasion suggests.

The charging current ought to vary with the capacity of the cell.

For 20 ampere-hour cells, use 2 to 2·5 amperes.

„ 30	„	„	„	3 to 4	„
„ 40	„	„	„	4 to 5	„
„ 60	„	„	„	6 to 7	„

These values of current are not necessary. Other values may be used, especially weaker ones. Much stronger currents must be avoided, as they tend to disintegrate the plates. If weaker currents are employed, they must be maintained a proportionally longer time.

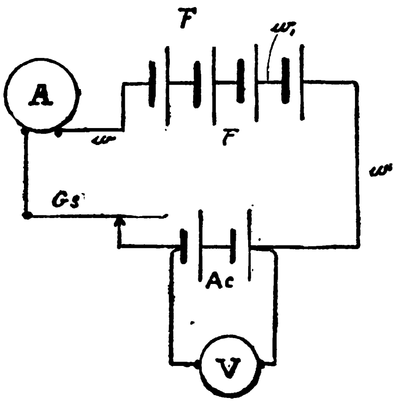


Fig. 57.—Charging circuit diagram.

The charging ought to be continued till:—

(*a*) The colour of the plates is completely restored: the positives a rich dark brown; the negatives a fine grey-blue.

(*b*) The density of the acid is about 1,220.

(*c*) The voltage at the outer terminals (during charge) is about 5·0 or 5·2 volts.

(*d*) Gas bubbles are coming freely from both the negative and positive plates.

It is important to notice (*c*) if possible. At the end of a "charge," an accumulator has a temporarily high

voltage, about 2·5 or 2·6 volts per cell (or 5·0 to 5·2 volts for two cells). This is due to temporary rise of acid strength in the pores of the positive plate, the excess being brought there by the current. When the charge is ended, the strong acid diffuses out of the pores and the voltage falls gently down to its normal value. This ought to be about 2·05 volts per cell; 4·1 volts for two.

Fig. 57 gives a diagram of a battery of two accumulators, *A c* being charged by four Fuller cells *F*. An ammeter *A* and a German silver wire *G S* are included in the circuit. A voltmeter *V* is joined across the terminals of the accumulators so that the pressure can be read at any moment. It will be noticed that each cell is represented by very simple symbols: a long and a short line. The long line represents the positive plate and the short line represents the negative plate.

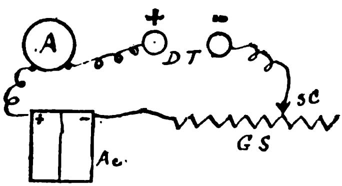


Fig. 58.—Charging by dynamo.

Further, the negative plate of the first cell is joined by a short wire w_1 to the positive of the second, and so on in series. The arrow-head touching the German silver wire is to indicate that more or less of the wire can be introduced into the circuit by sliding the contact to right or left.

62. **Recharging by Dynamo**.—This can only be done efficiently when the dynamo is one that gives a low voltage, say from 6 to 10 volts. It is then joined to the accumulators as in fig. 58, the dynamo taking the place of the Fuller cells. The only precautions needed are first, start with a greater length of German silver wire *G S*, so as to be able to have greater control of the current; secondly, see that the positive terminal of the dynamo is joined to the positive terminal of the battery. *D T* are the dynamo terminals, *A* an ammeter, *G S* a

controlling length of German silver wire. The arrow-head indicates a sliding contact *S C* putting more or less of *G S* in circuit.

How to recognize the positive terminal is an easy question to answer. The best way is to take two clean strips of lead, fasten wires to one end of each, and introduce the other ends into dilute sulphuric acid (1 to 6) contained in a large dish. Keep the lead strips well apart. Now hold the free ends of the two wires in contact with the terminals of the running dynamo for a few minutes. A current will flow through the acid, and the lead strip connected with the positive terminal will be turned brown by the formation of a layer of peroxide of lead. This positive terminal must be joined to the

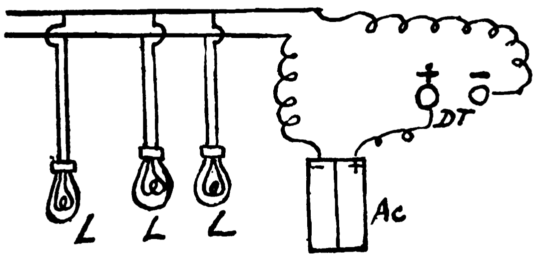


Fig. 59.—Charging from high pressure dynamo through lamps.

positive of the accumulators and the rest of the connections as in fig. 56 or 57, with or without the ammeter.

There is another way of identifying the poles, namely, by "pole-finding paper." A bit of this paper is moistened with water, and then wires from the dynamo terminals held in contact with the moist paper some distance apart. After a few minutes the paper touched by one wire turns red. The terminal of dynamo joined to that wire is the *negative*, and must be joined to the negative of the accumulators.

If the dynamo gives a high voltage (50 to 250 volts) it is better to join it to lamps as if for lighting purposes, introducing the accumulator as in fig. 59. One terminal of the dynamo is joined to one main direct. The second

dynamo goes to the other main through the accumulator *Ac*. It is essential that the connections should be pos. to pos. and neg. to neg., as suggested, but immaterial whether the direct connection to the cells is made by the positive or by the negative end. The positive main can be identified as in last paragraph.

63. **Recharging from Lighting Mains.**—This can be done easily if the mains yield a continuous current, but not if they provide an alternating current. The plan consists in joining the accumulator across the contact points in a switch controlling one or more lamps. The only point demanding care is to see that the switch bar itself does not touch these points. If by any accident this should happen, the accumulators will be short circuited and seriously injured.

Fig. 60 indicates the method. Every switch has two contacts, such as *a* and *c*; also a connecting bar or plug such as *b*. As long as *a* and *c* are disconnected no current can flow to the lamps; as soon as they are joined together a current will pass If two wires be joined to *a* and *c* and brought to the accumulator, the battery will be charged, provided that the current is passed through in the right way. A preliminary experiment must therefore be made to find which of the two wires from the switch represents the positive: see par. 62.

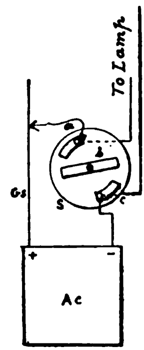


Fig. 60. Charging from switch.

To provide against the risk of injuring the battery should the bar *b* be accidentally put "on," it is better to use about a yard of German silver wire, No. 22, for one of the connecting wires.

The charging current is determined by the number and the character of the lamps which are controlled by the switch. As a rule the number of lamps cannot be altered in cases like that here discussed, this plan only being adopted where others are too inconvenient. The switch chosen probably controls one or two lamps. The following table will show what the current is in all ordinary cases. It should be explained that in electric

lighting nearly all the lamps are arranged in parallel across the mains, so that the current increases as the number of lamps increases.

Voltage of Supply.	50	100	150	200	250
Number of 16-candle power lamps required to get 1 ampere approximately ...	1	2	3	4	5

From this it is clear that at 100 volts supply a 16-candle power lamp takes about half an ampere; at 200 volts only about a quarter of an ampere, and so on. At any given voltage, a 32 c.-p. lamp takes twice the current, while an 8 c.-p. takes half as much.

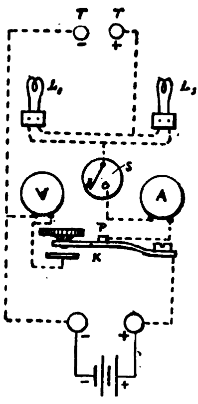


Fig. 61.
Charging board.

The temporary and somewhat unsatisfactory method of charging described in this paragraph has led to the construction of charging boards for garage use. A plan of such a board is given in fig. 61. The top terminals *T T* are joined to the mains; the bottom ones to the accumulator, as shown. Care must be taken to join the positive terminals in each case. When the lamps L_1 L_2 are put in their sockets, and the switch *S* is put down, a current flows through the lamps and accumulators whose value depends largely on the resistance of the lamps. If they are of the voltage proper for the circuit, the current will be about right.

It will be observed that the current passes through an ammeter *A*, and also through part of a key *K*. The contact *P*, by which the current enters the key, is fixed, and the key makes contact only so long as it is not

depressed. It is introduced so as to allow the charging current to be stopped, and also permit the pressure of the cells to be read. When the key is depressed, the *main circuit* is broken, and at the same time the accumulators are fixed to the voltmeter *V*. From its reading the stage of the recharging can be judged.

Alternating current mains are quite useless for recharging purposes unless a "rectifier" be employed. Rectifiers are expensive.

64. **Current, Electromotive Force.**—Motor men find a great difficulty in distinguishing between these terms. In trying to make it easier, we shall fall back on the analogy with the circulation of the blood. If it is clear what is meant by the words in one case, it will be easy to follow the other case.

Current.—Current is measured by the quantity passing per second. In the case of the blood, this means the number of ounces of blood passing out of or into the heart per second. In the case of electricity, it means the number of units of electricity passing into or out of a cell or lamp per second.

A current of electricity suffers no diminution as it flows, no more than the blood suffers loss in passing through the arteries and veins. As much blood enters the heart as leaves it. Of course there is loss, but it is not a loss of current. It is a loss of pressure. As the blood leaves the heart, it has been put under pressure, which urges it along the arteries. The pressure is diminishing all the way round back to the heart. The current that enters has lost *its pressure;* it has not diminished in any other way, as much blood passes in per second as passed out.

The same truth holds for electricity. As the current leaves a cell or magneto, it has an electric pressure or voltage on it. This is gradually spent in urging the current along the circuit, and is quite gone by the time the current reaches the negative terminal. The cell restores the pressure on the current as the electricity flows through it, just as the heart restores the pressure on the current as the blood circulates through it.

65. **Measurement of Current.**—The true way to measure any current is by stating what quantity of the moving stuff passes through some section of the path in one second.

Examples.—The current through London Bridge is say 50,000 *pounds of water* per second.

Or, the current of blood from the heart is say 1 *ounce* per second.

Similarly, we may say that the current of electricity through a lamp is 2 coulombs per second.

Here the quantity of electricity is measured in *coulombs*, and the reader will ask, "What is the coulomb?" He will say, "I know the quantity of water corresponding to a *pound*: I can find that out by weighing it. How can I find the quantity of electricity corresponding to 1 coulomb?"

Strange to say, this can be found by weighing. But the thing weighed is not the electricity, but the quantity of metal used in getting it. When a battery acts, the zinc in one or the lead in the other is burnt up chemically. Every grain of zinc burnt up yields 190 coulombs of electricity. Every grain of lead burnt up in an accumulator yields 60 coulombs of electricity.

The quantity of the metal used determines the quantity of electricity circulated.

Suppose a dry cell is used to get the current; some of the zinc is dissolved. Let it be weighed, and suppose the loss is 3 grains. Each grain means that 190 coulombs of electricity have circulated; the 3 grains dissolved indicate $190 \times 3 = 570$ coulombs. This is the *quantity of electricity circulated;* it tells us nothing as to the rate of flow or current.

Now suppose the 570 coulombs passed in one second. Then the current is 570 coulombs per second. Suppose the time was not one second but two, then the current is 285 coulombs per second, or half the value. Suppose the time were 570 seconds, then the current value was 1 coulomb per second. *This is the unit current.*

Put the same thing in another way. The unit current is one coulomb per second: one coulomb means the solution of $\frac{1}{190}$ grain of zinc in the battery. *Therefore unit current means the solution of* $\frac{1}{190}$ *grain of zinc every second.*

Electricians do not generally use the phrase coulomb per second. They say the unit current is 1 ampere, which is simply a brief way of saying 1 coulomb per second.

We may now say;—

The current from a dry cell is 1 ampere when the zinc is dissolved at the rate of $\frac{1}{190}$ grain per second. If the zinc dissolves at twice the rate, namely, $\frac{1}{95}$ grain per second, the current is 2 amperes (or 2 coulombs per second).

In an accumulator, the weight of lead yielding 1 coulomb is $\frac{1}{60}$ grain, therefore 1 grain yields 60 coulombs. If this weight is acted on in one second, the current is 60 coulombs per second or 60 amperes.

If 1 grain is acted on in 60 seconds, the current is 60 coulombs in 60 seconds = 1 coulomb in one second = 1 ampere.

66. **Electromotive Force.**—Using the analogy of the heart, the muscular pressure of the heart on the blood corresponds to the electromotive force of the battery. Two men may have the same current of blood flowing from the heart, though the pressure of one heart may be greater than that of the other.

In the same way, if a single dry cell and a single accumulator be joined to separate circuits, it is possible for them to maintain the *same currents*. Yet the pressure of the two is different. That of the dry cell is 1·5 volts, that of the accumulator is 2 volts. These different pressures arise from the different intensity of the chemical affinity in each case.

In the accumulator, the sulphuric acid is straining at the spongy lead in a more intense way than the sal ammoniac strains at the zinc in a dry cell. The more intense chemical strain sets up a greater electric pressure.

It will therefore be evident that the electromotive force does not depend on the *quantity of materials* in the cells, but on their chemical quality. A small dry cell gives the same electric pressure as a large one because the chemical affinity is the same. A large accumulator gives the same electric pressure as a small one, because the chemical affinity is the same.

But an accumulator gives a higher pressure than a dry cell, because the chemical affinities in the accumulator are stronger than those in the dry cell. The pressure or voltage of the accumulator is 2 volts, the pressure of a dry cell is 1·5 volts.

67. **Current from a Magneto.**—It has been explained that the current from a magneto is constantly varying,

and that it reaches a maximum value at a certain moment in the revolution. It was not exactly known at what point this maximum occurs, though there was reason to think it would be a little later than that shown in fig. 35. In connection with the growing use of the magneto, the question became rather important, and the author has therefore tried to settle it. Using a low tension magneto, he found figures which are embodied in the following curve (fig. 62). To appreciate the meaning and importance of this, it must be compared with fig. 37.

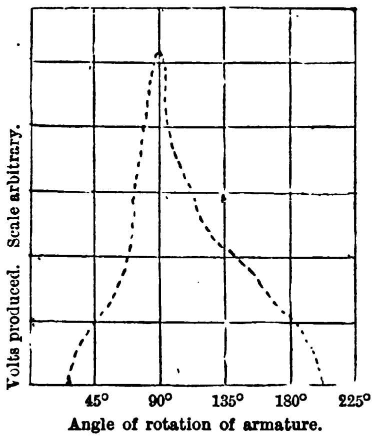


Fig. 62.—Variation of magneto current while running.

On doing this it will be seen that the voltage begins to grow later than in fig. 37, about 30° later. In other words, while the change ought to begin when the armature is in position fig. 33, it does not actually start till the iron core is about 30° further on.

Next, the maximum voltage comes exactly at the point shown in fig. 35, or 90° further on from fig. 33. This was true even when the armature was delivering 1, 2, or 3 amperes—a quite unexpected result. It indicates that the maximum pressure from a magneto will always come

at the same point, and that variations of speed and current will not alter the timing, although they may alter the actual magnitude of the voltage. This important conclusion is based on the facts that the maximum comes in the *same position of the armature*, whether as in fig. 35 the speed is slow and no current is taken; or as in fig. 62, the speed is high and a large current taken.

68. **Magneto *versus* Accumulator.**—The fact just stated throws much light on a long-standing controversy as to whether magneto ignition gave more power than a battery and coil. Most motor-men who carry both systems and start on the battery find that the car gives a bound forward at extra speed as soon as they switch on to the magneto, and it was therefore maintained that the magneto spark must give more power than the coil spark. But careful experiment disproves this. Prof. Watson, Mons. Bourdon, Mr. Percy Martin, and Mr. Edge have shown that the power is the same provided the coil is given more advance than the magneto. Suppose a coil working an engine and the advance adjusted. Now let a magneto be switched in. The spark will come a little earlier than before; in other words, the *advance will be increased*. The reason for this is simple. With a coil, the wipe or commutator is set by the timing gear to act at a definite time, say, when the piston is half an inch from the end of stroke. But the spark does not occur then. This only starts the primary current. The author has found that the spark comes about one-seventieth of a second later. Thus the piston will be much nearer the top of its stroke when the spark occurs, especially at high speeds. Some of the advantages of "advanced" spark will thus be lost. Now if the magneto be put on with the same timing gear, and its spark comes as soon as the gear comes into play (as is shown in fig. 62), the explosion will occur sooner and be more effective. But the balance can be restored by giving the coil more advance than is needed by the magneto.

The present tendency is to equip the best cars with both magneto and battery systems. The battery serves to start the engine, and the magneto is used to maintain the ignition during the run.

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